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THE TELEGRAPHIC JOURNAL AND

Electrical Review.

VOL. XX.—No. 491.

ELECTRIC MOTOR SYSTEMS.

WE have looked in vain for an adequate connection between the title and the substance of a paper by Mr. Stephen D. Field, recently read at a special meeting of the New York Electrical Club. The title of the paper is "The Construction and Operation of Dynamo-Electric Motor Systems," and the substance consists mainly of some very sketchy and ill-considered general observations on electric motors. So far as the construction and operation of a system is concerned, the paper gives no information at all. As the author says that "the criticisms, suggestions and theories" are put forward as the result of personal observation, we draw attention to some of them, but we should have been glad to have had more detailed information as to the actual facts on which he has relied in forming his opinions.

His assertion that there is no choice between the merits of the Pacinotti and Alteneck machines when similar amounts of wire and iron are used, does not agree with modern views. There is no doubt that the Alteneck armature possesses an advantage over the Gramme type as regards wire length, but is less easily ventilated and kept cool than the latter.

Mr. Field states his belief "that lamination of the pole pieces of a dynamo is of benefit in exposing a larger surface from which the lines of force may flow, and diminished heating results from this fact and not from the suppression of Foucault current, as has been by many assumed." Does he imagine that by merely increasing the polar surface of a magnet he will diminish any heating affecting the iron, and that this heating is caused by the mere steady flow of lines of force from the pole? The proposal for increasing the polar surface by lamination is certainly an odd one. Mr. Field must hold the opinion that a laminated armature is plentifully supplied with "polar surface." "It is difficult," he continues, "to see how Foucault currents could be generated in a piece of iron which is sensibly constant at all points to the flow of a steady current." It is. But does not Mr. Field know that eddy currents are never generated under such conditions, and that they are only produced in pole pieces when the armature has either iron projections or a small number of coils? The definition of a good motor possesses the virtue of explicitness. "The best motor," we are told, "is one that has a sufficient amount of wire on its armature to bring it to a magnetic strength exactly equal to the polarisation afforded by the field-magnet." Again, "a great loss occurs when the field-magnet does not have a properly polarised armature to act upon." Acting on these opinions it is not a matter of surprise that the author comes to the conclusion that automatic brush-regulation seems to be a necessity in motors. The sage reflection that "a dynamo without brush lead would be a monstrosity," because "the lead is due to the magnetic distortion caused by the opposition of the polarity induced by the current flowing in the armature, to the polarity given by the field-magnets," shows that Mr. Field's experience has not yet made him acquainted with any good modern dynamo, or he would have learnt that brush lead may be reduced to so small an angle as to be negligible. We advise him to give up his ideas on equal polarity, and he will then find that he can leave his brushes alone.

In this connection a trade trick is alluded to which shows what a respect for appearances some of the American manufacturers must have. We are told that they bend the wires back upon the commutator to give the line of commutation the appearance of being at right angles to the pole pieces, under the impression that this conveys the idea of great efficiency. China clay in our cotton is but a clumsy device, after this.

We fear Mr. Field has not solved the problem of constant current motors by his proposal to use shunt motors having much greater section of wire on the field than on the armature, and by means of a governor keeping always so much of the shunt wire in circuit as will maintain his *desideratum* of magnetic equality between the armature and field.

The paper winds up with some very good advice to electric light engineers not to waste their time on mechanical gymnastics, but to make use of their facilities, using what they have, and are sure of; promising them that they will make twice as much by the distribution of power as by lighting.

THE LOSS OF THE "VOLTA."

LAST Tuesday the sad intelligence reached London that the Eastern Telegraph Company's cable steamer, the *Volta*, had been totally wrecked at Myconos, Greece. The first accounts stated that Dunn, Blum, Draper, and Windle, and several of the crew were missing, that Boyes, Richardson, and Aldridge were still on the wreck, and that all the Greeks on board had been saved. A further telegram from Syra stated:—"Myconos office just come into circuit. Clerk informs me he was told that two boats were lowered, but immediately capsized by heavy sea, and several in them were drowned. Rest, numbering about 20, saved themselves by swimming, and seven or eight took refuge in the rigging, but as the weather is moderating it is hoped they are by this time rescued. Unable to give list of saved until return of steamer."

Wednesday's papers contained the following Lloyd's telegram from Syra:—"The *Volta* is a total loss. She struck at a spot about two miles from the south entrance of Panormo Bay, Nykono, at half-past three a.m. The following is a further list of the saved:—Captain Richardson; Gifford, chief officer; Menzies, chief engineer; Cole, chief steward; Bisset, carpenter; Sam Carcia, quartermaster; Darmanian, A.B.; Boyes, electrician; Bonniewell, second engineer; Maclaine, pantryman: Lackford, engineers' steward; Legate, storekeeper; Bonello, A.B. The following is a list of the drowned:—Captain Dunn; Messrs. Blum and Windle, of the electrical staff; Hill, chief cook; Costi Cavullo, second steward; Lampier, captain's servant; Scott, donkeyman; Bone, engineer's storekeeper; J. Krinnigas, fireman; V. Gallia, quartermaster; Frank Gallia, A.B. The *Volta* has sunk in 25 to 30 feet of water. The rigging will probably be saved."

FRANKLAND'S ELECTRICAL STORAGE BATTERY.

PROF. E. FRANKLAND, F.R.S., the well-known professor of chemistry, has recently patented some improvements which he has devised in storage batteries, the object aimed at being the avoidance of both buckling and the gradual detachment of the active composition from the metallic portion of the plates, both these effects being brought about by the expansion of the active material during the use of the battery. This is effected, firstly, by so enclosing or embedding the active composition in the metallic portion of the plate as to prevent its falling out, and, secondly, by giving sufficient strength to the plate to enable it to resist bending or buckling. Prof. Frankland employs as the active material the hardening mixture of oxide of lead and sulphuric acid, for which letters patent were granted to him in the year 1882 (No. 4,303), and whilst this mixture is in a pasty condition he moulds it into small cylinders or rods of convenient length and thickness, either by rolling, pressure through a draw-plate or tube, or other convenient means, and then flattens them on two opposite sides by pressure between two flat boards or otherwise. After these flattened cylinders have become sufficiently hard, they are placed in rows in a casting mould of dimensions corresponding to the size of the battery plate required and at such distances apart and from the edges of the mould, as to give sufficient space for the quantity of metal necessary to impart adequate strength and rigidity to the plate. Suitable molten metal, such as lead or an alloy of lead and antimony, is then poured into the mould until the interstices between the flattened cylinders are completely filled. In this way a plate is obtained, in which the active material is encased except on the flattened sides of the cylinders overlaid with metal, so that it cannot subsequently fall out during the charging and discharging of the battery, or even when subjected to considerable rough usage.

NOTE ON SECONDARY GENERATORS.

WRITING on the subject of secondary generators in the *Electrical World*, Dr. Louis Duncan of Johns Hopkins University says :—

Consider a secondary generator, as in the accompanying figure. Let *c* and *d* be the terminals of the primary, *a* and *b* those of the secondary.

The losses between these points due to the introduction of the apparatus are :

1. Loss due to heating of primary coil by the current. If the current follows a sine curve and C_o is its greatest value; R equals the resistance of the primary, then the loss in the primary will be :

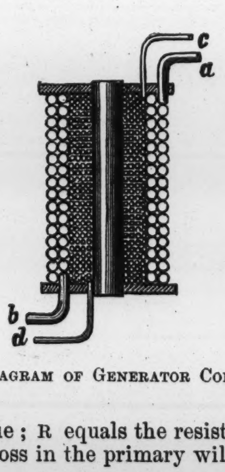

DIAGRAM OF GENERATOR COIL.

$$L_p = \tfrac{1}{2} C_o^2 R.$$

2. Loss due to heating of secondary coil by current :

$$L_s = \tfrac{1}{2} C'^2_o R'.$$

3. Loss due to currents induced in the mass of the iron. This is at any instant :

$$L = \mathfrak{M} \left[\frac{d\,\mathfrak{B}}{d\,t}\right]^2$$

where $\mathfrak{M}$ depends on the material of construction of the core.

4. Loss due to the reversal of magnetism in the core:

$$L_r = \tfrac{1}{4}\pi \int \mathfrak{B}\, d\, \mathfrak{H}$$

where $\mathfrak{B}$ is the magnetic induction and $\mathfrak{H}$ the magnetic force.

5. Slight loss caused by thermo-magnetic properties of the iron.

Of these (1) and (2) are well known and can be made small by making the corresponding circuits of little resistance. (3), due to so-called Foucault currents, can be reduced by laminating the core.

The loss appearing under (4) depends upon the retentiveness of the iron, and under certain conditions can assume large values. It is possible, as Dr. Hopkinson has shown, that the loss in a steel armature of a dynamo, from this cause, could be 20 per cent. ; for a wrought-iron armature it might be 4 per cent., providing there was no vibration ; there is a vibration in a dynamo at work, so it would be less.

But, considering this source of loss, a secondary generator labours under the disadvantage, when compared with an ordinary dynamo, that not only a part, but all of its mass is subject to reversals of magnetism, and it suffers no vibrations. As for the value of (4) then, I suppose (in the absence of data regarding current, reversals, dimensions of coils and core, &c.) that it is considerable as compared with the other losses. This loss is smallest when the core does not approach saturation and when it is made of very soft iron.

The loss under (5) is probably very small, and we need not consider it further.

All of these losses appear as heat in the secondary generator, and if proper precautions were taken they could be measured as such, and the efficiency of the system, calculated in this way, could be used as a check on the ordinary methods of measurement, which are very difficult to make accurately.

Of the experiments made on the efficiency of such generators, the value given by Dr. Hopkinson, *i.e.*, 86·1 per cent., is probably quite near the actual value. The "commercial efficiency," given as 95 per cent. by Prof. Ferraris, either means something else than is usually meant by that term (probably total efficiency of conversion), or is the result of miscalculation, as it does not agree with the tables given.

INDUCTION COILS GRAPHICALLY TREATED.

AN impression is prevalent amongst practical electricians, writes Mr. Gisbert Kapp in *Industries*, that the investigation of alternating currents, of their production by dynamo machines, and of their utilisation in transformers or induction coils, is a matter of extreme difficulty, requiring complicated mathematical formulæ, if we wish to reduce the working conditions of a given set of apparatus, and the results obtainable with it, to actual figures. We find in text books, and in articles which have appeared in scientific publications, elaborate mathematical expressions which are well calculated to justify the impression above alluded to, not only on account of their inherent complexity, but also because, being evolved on strictly scientific principles, and from laboratory experiments, the connecting links with actual practice on a large scale are often left obscure or entirely neglected. As a general rule, practical electricians have neither sufficient knowledge of higher mathematics, nor the necessary leisure to establish these connecting links for themselves ; in other words, to fish out from a mass of theory that which is of real practical importance, and to apply it to the actual design of apparatus ; these long and elaborate mathematical investigations are, therefore, of very little use to them. If it were possible to emancipate ourselves from theory altogether, and investigate the subject simply by experiments carried out on a large scale in the workshop, the results obtained would, no doubt, be more readily applicable to practical work than abstruse formulæ ; but, on the other hand, it would not be safe to generalise from such results. Experimental investigation of many mechanical problems, such as the lever, the screw, blocks and falls, &c., would by itself entirely suffice to obtain by generalisation a good working theory of these appliances ; but, in other cases, where the time element is of influence, our senses are insufficient to grasp the whole of the phenomena involved in the experiment, and, under these conditions, the attempt to generalise from experiments only must lead to erroneous results. Take, as an example, the case of an alternate current dynamo, working on a circuit which has considerable self-induction. A person having no theoretical acquaintance with the behaviour of alternating currents, would compute the rate of doing work in the circuit by simply measuring the current (say with a Siemens dynamometer), and the terminal pressure of the machine (say with a Cardew's voltmeter), and multiply the two. The product he would, generalising from his experience with continuous current machines, consider equal to the rate of doing work. But this would be completely wrong, because he would have neglected the time element, which cannot be grasped by his senses. It can, however, be very easily brought within the domain of calculation and measurement ; but, in order to do so, we must perform a theoretical investigation. Our theory, to be of easy application, should not only be as simple as possible in itself, but, what is even more important, it should take as a starting point some conception already familiar to the practical electrician, and it should give the final result in a shape and in terms also familiar to him.

In the following, the conceptions of magnetic lines of force, and magnetic resistance, both of which in the case of the continuous current dynamo have been generally accepted as the basis of its theory, are taken as the starting point. The text book method of investigating alternating currents is to begin with the assumption of a certain impressed E.M.F., then to introduce certain coefficients of self and mutual induction, and to establish for the resultant currents certain differential equations which, in some special cases, are capable of a fairly easy solution. If desired, the resultant magnetisation of the core can be found, as a last operation. In the present investigation, we shall reverse this order. We assume a certain magnetisation of the core, and proceed backwards, so as to obtain the impressed E.M.F. as a final result by a graphic method. After the graphic method has thus been fixed, it will serve also in those cases where the impressed E.M.F. is given and the other quantities are required to be determined. Before entering on the investigation, it is, however, necessary to make an assumption regarding the function according to which the impressed E.M.F. varies with time. It is customary to assume that the E.M.F. is a harmonic function, such, for instance, as would obtain in a coil revolving round an axis in its own plane with uniform angular speed in a uniform magnetic field. If A be the area of the coil, m the induction (number of lines per square centimetre of field) and ω the angular velocity ; and if we count the time, t, from the moment that the plane of the coil is vertical to the lines of the field, we find the number of lines threading through the coil at an angular position $\alpha = \omega\, t$.

$$Z = m\, A \cos \alpha.$$

The E.M.F. at that instant equals the rate of cutting lines at that instant, viz.,

$$e = -\frac{d Z}{d t}$$

and if we call T the time required for one revolution, and note that $\omega = \frac{2\pi}{T}$ we find the impressed E.M.F. in absolute units,

$$e = \frac{2\pi}{T}\, m\, A \sin \alpha.$$

This will be a maximum when $\alpha = 90°$, that is, when the plane of the coil is parallel to the lines of force. Let E be this maximum, then

$$e = E \sin \alpha$$

where $\sin \alpha = 2\pi \frac{t}{T}$ and $E = \frac{2\pi}{T}$ times the greatest number of lines which can pass through the coil. To obtain e in volts, we must express E in volts, viz.,

$$E = \frac{2\pi}{T}\, Z \times 10^{-8}$$

where $Z = m\, A$, the full number of working lines.

A familiar mechanical illustration of a harmonic motion is the apparently oscillatory motion of a crank pin, as seen end on. Suppose we look down on the crank of a well pump, then (neglecting the influence of the finite length of connecting rod) the position of the pin on the right or left of the centre line is a proportional measure for the speed of the piston at any instant. In other words, the horizontal projection of the crank radius will graphically represent the speed of the piston if the scale of the diagram is so chosen that the length of radius represents maximum speed. This method of representing varying quantities by the projection of lines revolving round a centre, is the basis of our graphic theory of transformers. It must be pointed out that the method can only give correct results if the quantities vary according to a true harmonic law, and the question naturally arises whether this is the case with the impressed E.M.F. in dynamo machines as actually constructed. As a general rule, it may be safely assumed that this will not be strictly the case. The impressed E.M.F., especially in machines containing iron in the armature, will vary according to a much more complicated law, and perhaps one which cannot even be expressed as a continuous mathematical function ; but the deviation from a true sine function has, in the few cases which have been experimentally investigated by Dr. Hopkinson and others, been found to be comparatively slight, and hence we shall not commit a very great error if we assume the sine function to hold good in practice. Another, and in itself sufficient reason for this assumption, is that the greater accuracy which might, perhaps, be obtained by taking a different function as basis of the investigation, would be accompanied by such complications as to render its easy and practical application impossible. Where the difference between the actual and the assumed function is great, a correction might be applied in the shape of a coefficient which could be found by experiment. In the following it is, therefore, assumed that the E.M.F., acting upon the terminals of either a single coil having self induction, or upon those of the primary of a pair of coils having self and mutual induction, is a simple harmonic function of the form

$$e = E \sin 2\pi \frac{t}{T}$$

where E is the maximum E.M.F. occurring at the times $t = \frac{1}{4}\, T$, $t = \frac{3}{4}\, T$, &c. ; and T is the time of a complete phase, consisting of two reversals. It is further assumed that the coils contain an iron core forming part of a completely closed magnetic circuit, so that the electric and magnetic circuits are relatively to each other in a position which might be familiarly described as that of two neighbouring links in a chain ; and that no leakage of lines of force takes place outside the core. The latter assumption is of special importance, because it is only under this condition that the same number of lines of force are cut at each reversal by every turn of the coils, and that the induced E.M.F. of each coil may be considered proportional to the total induction and the respective number of turns.

As regards the first assumption, viz., that of the threading of one circuit through the other, it may be as well to point out in this place that the exact manner in which the circuits are arranged is, on purely theoretical grounds of no importance, so long as in different arrangements the total magnetic flow through the core, and the total current turns through the coils, are the same. From a practical and commercial point of view, however, that arrangement will evidently be the best in which both the path of the lines and the length of wire in the coils are reduced to a minimum. Thus a ring shaped inductor wound in the Gramme fashion, that is, with the iron inside and the copper outside, will not be as economical in weight of materials used as the inverse arrangement of copper coils inside, and iron wire wound over them to form the outside. In the following we shall, however, not limit the investigation to any one special arrangement, but simply assume that the conditions mentioned above are fulfilled. It is evident that the phases of induced E.M.F's. and currents must all be equal to, though not coincident with, that of the impressed E.M.F., and each of these quantities can be represented by a similar function to that given above, viz., as the product of a maximum value, and the sine of an angle.

1. *Single Coil.*—If the greatest induction in the core remains within the limit for which direct proportionality between exciting power and total induction can be assumed, the induced E.M.F. remains proportional to the current. Let $i = I \sin \alpha$ and $z = Z \sin \alpha$ represent respectively the current and total induction (total flow of lines), I and Z being maximum values, and $\alpha = \frac{2 \pi t}{T}$. In establishing these equations, it is assumed that the actual magnetisation is, in phase, coincident with the magnetising current (exciting power), and that there is no difference between an ascending and descending magnetisation. The first assumption is probably correct, whilst the latter is not; but, by subdivision of the iron core, the error can be somewhat reduced. It should also be noted that another error, due to saturation, tends to compensate for the neglecting of hysteresis, and, for the sake of simplicity, both these errors are assumed to be unimportant, and are neglected. If the coil consist of τ turns of total resistance r, the induced E.M.F. at any moment is $\tau \frac{d z}{d t}$, and the E.M.F. required to overcome the resistance is $r\, i$. Writing e_ι and e_ρ for these quantities, and E_ι and E_ρ for their maxima, we find the impressed E.M.F. e by adding e_ι and e_ρ.

$$e = E_\iota \cos \alpha + E_\rho \sin \alpha;$$

and since this must evidently be a sine function, we can write $e = E \sin (\alpha + \phi)$; where ϕ is a certain angle smaller than $\frac{\pi}{2}$.

The value of ϕ is found from the consideration that for $\alpha = 0$, $e = E \sin \phi$; and for $\alpha = \frac{\pi}{2}$, $e = E \cos \phi$;

$$tg\, \phi = \frac{E_\iota}{E_\rho};$$

$$E_\iota = \frac{2 \pi}{T} \tau Z; \quad E_\rho = r I; \quad Z = f(I).$$

For low degrees of magnetisation, the function of I, which gives the total induction Z, takes the form of a constant factor depending on the quality of the iron, and the configuration of the core. It can, with sufficient accuracy for practical purposes, be represented by

$$\mu \frac{4 \pi \tau I}{\frac{l}{a}},$$

where μ is a coefficient varying with the quality of the iron, l is the mean length of the path of the lines, and a the cross section of the core, which we assume to be uniform. Writing R for $\frac{l}{a}$, and K for $\mu\, 4 \pi$, we have

$$Z = K \frac{\tau I}{R}.$$

In this expression, R represents the magnetic resistance, and the influence of higher degrees of magnetisation can be taken into account by multiplying $\frac{l}{a}$ with a factor depending on the degree of magnetisation. This factor can either be obtained from curves of magnetisation such as given by Dr. Hopkinson in his paper on the "Magnetisation of Iron,"* or by the adoption of an empirical formula. From experiments on dynamo machines, I have found the factor tang $\left(\frac{\pi \sigma}{2}\right) : \frac{\pi \sigma}{2}$ (where σ is the ratio of actual induction to the possible maximum induction) to give fairly satisfactory results.

A. *Disregarding the saturation term.*—The formula for the impressed E.M.F. is capable of graphic representation. Starting with a given maximum current I, we find the corresponding total induction and the values E_ι and E_ρ, by calculation, the resistance of the coil, number of turns and configuration of the core being supposed to be given. In the diagram (fig. 1) O E the maximum impressed E.M.F., and the lag ϕ are found graphically from the known values of E_ι and E_ρ by constructing the triangle O E_ρ E. The current at any moment is proportional to the projection of either O E_ι or O E_ρ on the vertical O Y, and the impressed E.M.F. is proportional to the corresponding projection of O E on the vertical; both these quantities can, by suitably choosing the scale, be read directly off the diagram. The variations in the impressed E.M.F. and in the resultant current strength are thus represented by the variations which the projections of the two lines O E and O E_ρ undergo whilst these lines are revolving round the centre O, the former being always in advance by the angle ϕ. In other words, the current lags behind the impressed E.M.F. by an interval of time represented by this angle. It is evident that the lag is independent of the impressed E.M.F., but increases if the resistance is decreased. Assume now that the condition of the apparatus represented by the diagram is well within the limits for which direct proportionality between magnetising force and total induction can be assumed, then an increase or decrease of impressed E.M.F. will produce a corresponding increase or

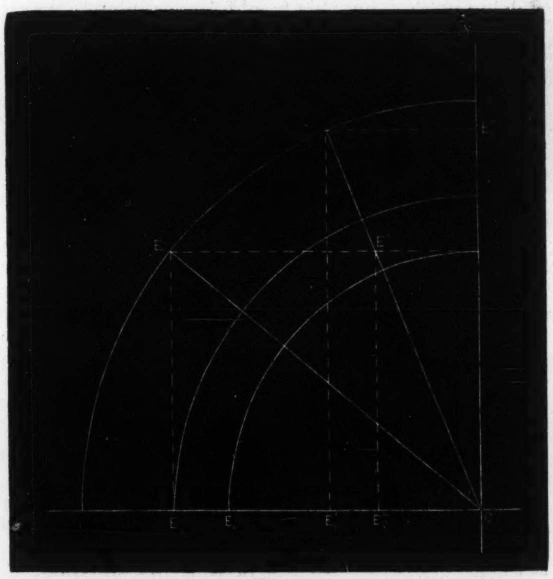

FIG. 1.

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* Philosophical Trans. Royal Society, 1885.

decrease of E_ι, E_ρ, and I, without alteration in the angle of lag. If the resistance, r, be diminished, the current will increase, and *vice versa*. This can easily be seen from the diagram. Let O E_ρ''/O E_ρ represent the ratio in which the resistance has been diminished, and assume for a moment that the current has not altered. This could be attained by a suitable reduction of impressed E.M.F. from O E to O E′. The new angle of lag is now ϕ'. But if the impressed E.M.F. has not been reduced, all the quantities must be increased in the ratio O E/O E′, and we find O E_ι' and O E_ρ' as the true values of E.M.F.'s due respectively to induction and resistance. If the scale for the current has been so chosen that O E_ι represented the current before the reduction in resistance took place, the length O E_ι' gives at once the new current, and it will be seen that even were it possible to reduce the resistance to zero, the current could not exceed the value O E. The case here considered is of importance when arranging arc or glow lamps in parallel between a pair of mains fed from an alternate current machine. In this case, a coil having self induction (termed by Mr. Gordon, who originated this system, a "choking coil"), is placed in each lamp circuit. The resistance, r, consists, then, of two parts, that of the lamp, which we may regard as free from self induction, and that of the coil, which has a considerable self induction. The resistance of the coil is, however, comparatively low, so that there is a very large difference in the resistance of each branch when the lamp is properly burning, and when, by design or accident, it is short circuited. Notwithstanding this great difference, the current passing in the latter case need not be very much larger than the normal current, and since its angle of lag is nearly 90°, the waste of energy is only trifling. A simple calculation, which need not here be given, shows that if hysteresis be neglected, the waste of energy is only due to the resistance of the choking coil, which, of course, can be made very small.

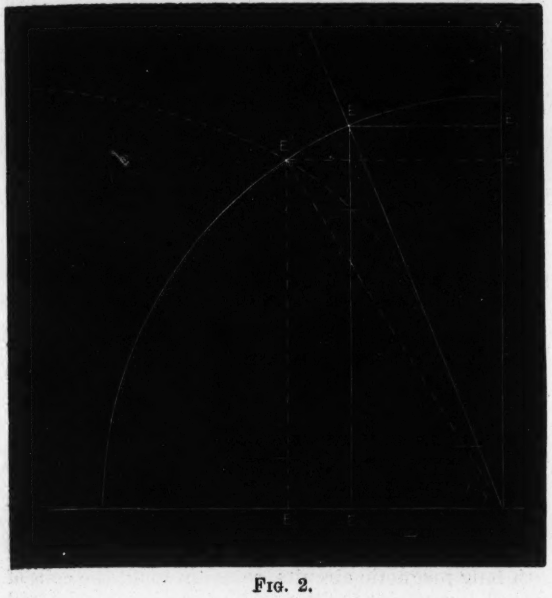


FIG. 2.

B. *Taking the saturation term into account.*—Only a slight modification of fig. 1 is required to obtain an approximate solution of the problem in the case that the iron core of the coil is so small as to become saturated. In that diagram, O E is a line drawn under such an angle, ϕ, to the horizontal, that its projection on the vertical may be considered to graphically represent to a suitable scale the total induction, whilst its projection on the horizontal may similarly be considered to represent the magnetising force. In fact, we may consider O E to be that portion of the characteristic of magnetisation which, on account of its proximity to the origin, is a straight line. In fig. 2, this characteristic, shown dotted, is prolonged. If saturation did not intervene, the current would, to a suitable scale, be represented by the length, E E_ι, and the E.M.F. of induction by the length, O E_ι, the angle of lag being ϕ. But since, on account of increased magnetic resistance with approaching saturation, the current does not produce the full induction, the E.M.F. of induction must be smaller than O E_ι. If the magnetic resistance were constantly maintained at its increased value, the intersection, E′, of the circle representing the impressed E.M.F. with the characteristic would give the point the projections of which represent, as before, current and induced E.M.F. On this supposition, the angle of lag would be ϕ', the current would be E′ E_ι' (measured with the same scale as previously), and the induced E.M.F. would be O E_ι'. The current now found is evidently larger than E E_ι. But the magnetic resistance is not constant, it has its initial or minimum value at the moment when the induction and current pass through zero, and it has a maximum value when the induction and current are maxima. If we construct the diagram on the assumption of constant minimum magnetic resistance, we obtain the current E E_ι, which is evidently too small, whilst the angle of lag is too large; if we assume constant maximum magnetic resistance, we obtain the current E′ E_ι', which is evidently too large, whilst the angle of lag, ϕ', is too small. The true values lie somewhere between the points E and E^1, probably nearer the latter, because hysteresis, which has been neglected, must operate in the same direction as an increase of magnetic resistance, and is of greatest influence at those moments when the magnetic resistance is a minimum. As an approximation sufficient for most practical purposes, E′ E_ι' can be taken as the true value of the current.

It will be seen that an increase of impressed E.M.F. as soon as the knee of the characteristic has been passed, result in a comparatively large increase of current. In other words, the choking power of the coil begins to break down after this point, and under increased pressures its action approaches that of a resistance without self-induction.

(*To be continued.*)

ELECTRICAL DISTRIBUTION BY ALTERNATING CURRENTS AND TRANSFORMERS.

By RANKIN KENNEDY.

TRANSFORMERS—(*Concluded from page* 347.)

THE numbers of modifications of the closed magnetic circuit is very great, in fact any form of dynamo armature makes a good transformer, thus, besides the forms already described, we can use a laminated drum armature of Siemens type with an outer iron sheathing, or, better still, an armature of the same type with projecting teeth, such as the Weston armature, with an outer iron wire, or plate, sheathing, and thus form a subdivided transformer. Pole armatures of the old Lontin type may be also used with success when properly laminated with an outer sheathing, as in fig. 19. The two conductors are wound on the poles as shown; A is an end view of the laminated iron core with C, C, C, C, and B is the iron sheathing. All these modifications are equally efficient and perfect self-regulators, and the only question to be decided by the maker is which form is the cheapest to manufacture; the question for the intending buyer of transformers is which form is the easiest to keep in repair and cheapest in first cost.

Enough has been said about the construction of transformers to show that it is one of the simplest pieces of electro-magnetic apparatus imaginable. Simply, it consists of two insulated electric conductors combined with an iron magnetic conductor. The only room for improvement lay in this iron conductor, and the experience gained in dynamo building is all applicable in this direction.

We may now enquire into the practical rules for the construction of transformers. Hitherto no definite numerical rules have been published. Transformers have received most elaborate treatment in the hands of mathematicians, and a vast array of formulæ could be here introduced with a view to elucidate the theory of the construction, but I don't think that would be of any use to practical electrical engineers. In this place I am persuaded that a few simple rules within the capacity of any intelligent workman will be much more useful.

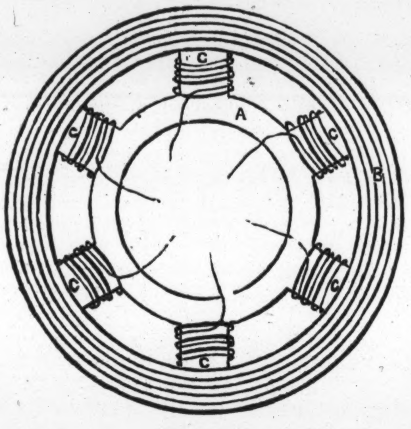


FIG. 19.

In making a transformer the first question is, of course, what form of iron magnetic circuit is it to have? The choice lies between the Zipernowski type or the subdivided type, as these have by far the lowest magnetic resistance and can be perfectly laminated, being equally efficient and self-regulating. The choice must be decided on the score of practical convenience for repairs and ease of manufacture. After deciding upon the best form of iron organ for the transformer, the most important question next, is what length of wire shall be required for primary and secondary conductors? Upon these lengths depend the most important function of self-regulation and economy in the transformer.

The length must be found for self-regulation according to the laws—

1. When no work is being done in the secondary circuit there should be no current in the primary circuit —that is, the counter pressure in the primary must be equal to the primary pressure, or very nearly equal thereto.

2. As the current increases in the secondary circuit the current in the primary should increase proportionally in the ratio of the transformer—that is, the counter pressure in the primary should fall as work is increased in the secondary.

Here I may observe that there is an impression abroad that the mere employment of the fine wire as primary and the thick as secondary in an induction coil was a great invention made only recently, I am certain that this has been tried by innumerable experimenters during the past 30 years.

To be of any use the wires must be wound to satisfy the laws, irrespective of their thickness or thinness, and then they must be employed in combination with main conductors at constant pressure, and if more than one is to be operated at one time they must be connected in parallel order, and they must be constructed accurately with a fixed ratio. All these imperative requirements are not stated, described or claimed in any one patent yet issued, and yet none of them can be neglected in a system of distribution by alternating currents and transformers.

As the rules for finding the correct lengths, and the reasons for them are obvious enough to those who could follow, I will simply state them as :—

Rule 1.—To find the lengths of the primary and secondary conductors in a transformer for reducing from a high to a low pressure, divide the primary pressure by the coefficient of induction in the primary circuit (that is, by the induction in volts per foot of wire), this will give the length in feet of wire for primary.

Rule 2.—Divide the secondary pressure by the coefficient of induction in volts per foot, this will give length in feet of wire for secondary.

In the best transformers working with about 200 alternations per second this coefficient is very high and averages about 2 volts per foot, and that may be taken as the figure for use in the above rules; for example :—

Given a primary pressure of 1,200 volts, and the required secondary pressure given as 80 volts, what lengths of primary and secondary wire should be employed? Answer, $\frac{1{,}200}{2} = 600$ feet for primary, $\frac{80}{2} = 40$ feet for secondary. These lengths do not include wire not under induction.

If the alternations are not so rapid this coefficient becomes less. It might be argued from this fact that as it is perfectly easy to make the alternations very much more rapid than 200 per second, that, say 500 or 1,000 alternations should be adopted. There is a limit to that; as the alternations increase in number per minute the losses in the transformer increase, and that fact often accounts for different efficiencies being found for the same transformer by different experimenters—the one, perhaps, has employed the alternations for which the transformer was calculated, the other has employed slower alternations and therefore no agreement could be come to. It is, therefore, necessary to ascertain by experiment the coefficient of induction for each type of transformer at a given alternation rate. In transformers with long magnetic circuits, common to all the coils of wire, the coefficient will not be higher than 1·5, and often falls as low as 1 foot per volt.

Practically this coefficient may be found by taking the given alternating pressure having the given rate of alternations through an approximately correct length of primary wire on the transformer, say a length calculated at 2 volts per foot (the secondary circuit being open or not yet wound on), and measuring the current produced through this length. If no measurable current is observable then that is the correct length; there should be some current, of course, say, perhaps, two per cent. of the maximum current. If the coefficient of induction is less than that calculated upon, a considerable current passes in the primary when no secondary current is flowing. The primary wire must, in that case, be increased in length until this initial current disappears, or becomes so small that it is of no account, and then the length of secondary can be calculated by the rule.

Rule 3.—The ratio of a transformer is found by dividing the primary pressure by the secondary pressure, thus in my previous example—

$$\frac{1{,}200}{80} = 15.$$

15 would be said to be the ratio of that transformer, and thus

	Primary.		Secondary.
The pressures are to each other as	15	to	1
The lengths of conductors to each other as	15	„	1
The cross-section of conductors to each other as	1	„	15
The currents to each other as ...	1	„	15

The iron conductor of magnetic force should not at any time be anywhere near half saturation; it should therefore have large cross sections, and data for calculating its size may be obtained from dynamo builders.

The application of these rules to transformers for *raising* the pressure is obvious, only I may point out that in this case the short thick wire is the primary, and the coefficient of induction must be found for it, and the lengths calculated from this coefficient. Of course the initial current allowable in the primary circuit may be comparatively large (the initial current is the current flowing in primary with no current in the secondary circuit), thus we may have in the transformer primary circuit, with full load on the secondary, 100 ampères at 100 volts pressure; while with no load in the secondary we may have only 5 ampères, or only 5 per cent. of initial current; of course, by increasing the length of the wire, we lower this initial current, but we also lower the coefficient of induction per foot of wire.

Those who wish to study the exact science of the subject should study Mascart and Joubert's work, Hopkinson and Ewing's publication, and the articles by Kapp now appearing in *Industries*.

Its high efficiency, combined with its great simplicity of construction, is bound to recommend the transformer for many applications not yet thought of; it must prove a powerful machine in the hands of electricians when they become better acquainted with it practically. The application of the transformer to electric welding is an example in point. I have recently employed a small transformer for multiplying or dividing the readings of an alternating voltmeter, and by this means I can employ any ordinary alternating current voltmeter, reading between, say, 10 volts and 120 volts, to measure alternating E.M.F. up to any pressure, say 5,000 volts.

A Cardew voltmeter combined with a transformer whose ratio is say 20 to 1 may be connected to the secondary conductor, or, more properly speaking, to the low pressure conductor; the pressure to be measured is connected to the high pressure conductors, then the readings of the voltmeter have only to be multiplied by the ratio 20 to give the exact pressure in the primary; if the voltmeter indicates 100, then the pressure is 2,000, and so on for any pressure. If we use a transformer having a ratio of 50 to 1, we can just as easily measure 5,000 volts. By this means it is possible to multiply extremely low E.M.F.'s and measure it on ordinary voltmeters. The ratio is constant enough for all practical measurements of alternating E.M.F.'s.

In conclusion, I may say that these notes on this interesting subject have not been very carefully arranged, and might have been extended to some advantage on some of the points, but the subject is already a large one, and requires the expenditure of valuable time in writing up even without any polishing.

I hope, however, to return to the subject, with the kind permission of the editors of the ELECTRICAL REVIEW.

Something might be said about the dynamos, but there is really no new feature to notice about the later alternating dynamos; they are all old types built with the experience and knowledge obtained from continuous current dynamo evolution.

The rule being to make the magnetic field as powerful as possible and to shorten the length of wire in the armature as much as possible; as the field gets stronger and the armature wire shorter, so the dynamo improves.

THE ELECTRIC LIGHTING OF THE SALTAIRE EXHIBITION.

THE electric lighting arrangements for the Saltaire Exhibition, which is to be opened on May 6th by Princess Beatrice, are now in an advanced state, and it is expected that the whole system will be in working order during the ensuing week. Ten dynamos will be brought into use; eight of these have been supplied by Messrs. Mather & Platt, Salford. The current will be sufficient to supply 150 arc lamps of 2,000 candle-power each and 600 incandescent lamps. Ten of the arc lamps are to be used for lighting the great concert-hall, there will be four arc lamps in each court, and arc lamps will also be used for lighting the picture galleries in the new science and art school. The bulk of the remaining arc lamps will be disposed about the grounds, which will thus be brilliantly illuminated at night-time. Then, in addition to these, there will be a great 50,000 candle-power lamp in the lighthouse lantern, the current for which will be supplied by a separate dynamo. The arc lamps will all be arranged in four separate circuits, so that in the event of a failure in any one circuit only one-fourth of the lamps will be affected, and a sudden transition to total darkness becomes thus practically impossible.

The incandescent lamps will be used to light Princess Beatrice's reception room, the private dining rooms, the offices at the main entrance, the Japanese Village, the carriage-court, the hand woolcomber's cottage, the class-rooms and lavatories in the new science and art schools, the subway, corridors, and grottoes, and the refreshment-rooms. The band-stand in the grounds and the great organ in the concert-hall will also be lighted with these lamps. Altogether about 400 lamps will be required for this work, and it is anticipated that the private requirements of exhibitors will bring the number of incandescent lamps up to 600. The wiring in the science and art schools has been done as for a permanent installation, and each room is provided with a separate switch, so that if it should be decided to use electricity for lighting the schools, when the exhibition is a thing of the past, there will be no further expenditure on this head. The fittings and brackets for the Royal apartments are most elegant in design. The whole of the various circuits are controlled by a main switchboard placed close to the dynamos. One feature which will doubtless prove very attractive to visitors is an arrangement by which they will actually be able to see the dynamos at work. A gallery is being constructed almost immediately above the long range of dynamos, from which the most timid spectator may look down upon the machines at work.

The power for generating the electric currents will be supplied by engines and boilers specially designed for this kind of work, and supplied by Messrs. John Fowler & Co., Limited, of Hunslet, Leeds. Altogether there are three engines and boilers, with an effective total of 330 horse-power. Two of the engines are of the semi-portable type, with locomotive boilers, the engines being placed on a cast-iron frame underneath the boilers. Both these engines are compound, the smaller one, of 60 horse-power, having a high-pressure cylinder of 8 inches diameter, and a low pressure cylinder of 14 inches diameter, with a stroke of 16 inches. The cylinders of the larger engine, which is of 120 horse-power, are respectively about 12 inches and 21 inches diameter, and the stroke is 24 inches. The engines are fitted with Hartnell's automatic expansion gear, and the working pressure of the boilers, which are of steel, is 140 lbs. on the square inch. The third engine is a two-cylinder high-pressure engine of 150 horse-power, coupled on one crank shaft, with cylinders 13 inches in diameter, and also fitted with Hartnell's automatic valve gear. Steam for this engine will be supplied by an immense boiler of the locomotive type, resting on foundations adjacent to the engine. This boiler weighs over 10 tons, and the makers have supplied several of the same class for electric lighting work at Eastbourne and elsewhere. The piston speed of all the engines is the same, viz., 360 feet per minute. All the engines drive on to a main shaft, 4½ inches diameter and about 45 feet long, which is divided into three sections, coupled by sliding-sleeve clutches, so that any one of the three engines may be thrown out of gear without the necessity of throwing off the driving belts. The dynamos will all be driven direct from this main shaft, on which there are about 15 wrought-iron pulleys of different sizes, by Metcalf, of Bradford.

The installation has been entirely carried out by the Bradford branch of the Woodhouse and Rawson Company, under the superintendence of Mr. Harris and Mr. Ray.

It may be stated that on the opening day Princess Beatrice will start the whole of the machinery in the exhibition by sending a current through an electro-magnet, which will control the lever of a "barring" engine used in conjunction with the main engine of the machinery in motion section.

LONG DISTANCE DISTRIBUTION OF ELECTRIC ENERGY.

IN both the Gaulard and Gibbs and the Zipernowski-Déri systems, alternating dynamos and alternating currents are used from the beginning to the end, with the result that all electrical apparatus requiring continuous currents, as, for instance, motors, secondary batteries, electro-plating apparatus, and almost all the different types of arc lamps in use in America, are debarred from utilising the current furnished by these systems.

This is a very serious defect, and demonstrates the incompleteness of both systems, especially where, as in America, rapid progress is being made with the introduction of motors into factories and private houses. That those systems, and especially the Zipernowski-Déri system, have been able to do good work in Europe in spite of the great defects mentioned above, proves the great demand there is for this kind of work, rather than the perfection of the systems themselves.

To realise a system avoiding the defect pointed out, the alternating dynamo must give way to the continuous current machine, and a simple, effective, and sparkless current alternator must be inserted in the high tension circuit at that point from which it is proposed to send out alternating currents to supply the induction coils, while the continuous current circuit is used to supply motors, lamps, batteries, &c. The very use of continuous current dynamos gives the advantage of a higher efficiency of the first over the latter, while it is well known that there is less danger in handling a continuous current machine than an alternating one, and that alternating dynamos cannot be coupled in series. Furthermore, it is far more difficult to obtain the good insulation necessary in dynamo machines of high tension for alternating current than in those for continuous current, on account of the peculiar properties of the former.

A system to be complete and flexible and capable of serving all legitimate purposes must, therefore, embrace a continuous current high tension dynamo (like those in use on arc circuits at present), a continuous current circuit, a current alternator near the dynamo, a high tension alternating main circuit, a high tension alternating local circuit and a low tension great density local circuit; the last but one to be preferably multiple arcs off the alternating main circuit.

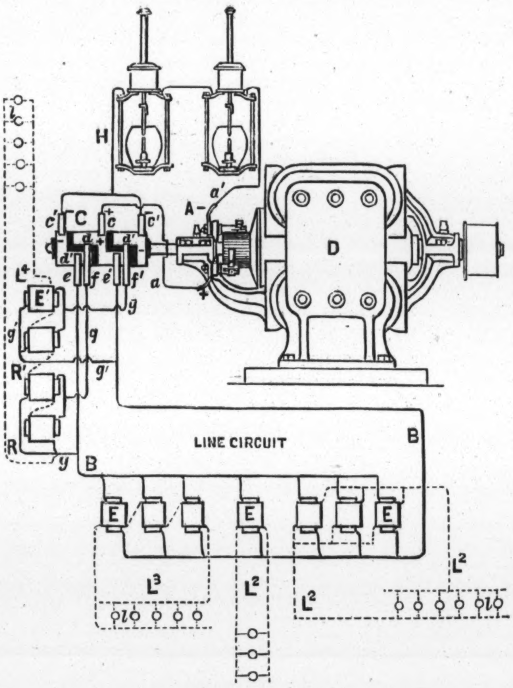
Such a system has been devised by Mr. A. Pfannkuche, in conjunction with Mr. G. Pfannkuche, and the former states in the *Electrical World* that preliminary experiments with the combination have shown it to be very successful, especially when employing secondary or induction coils of a new construction.

The current alternator—there is only one for each plant used by the writer—is the result of many trials, and is of very simple and cheap design. It rapidly changes the direction of the continuous current without a possibility of sparking even with the heaviest currents, and without the slightest chance of ever breaking the main circuit, thereby insuring the absence of disturbances in that part of the circuit where steady continuous currents are required, and without any loss of energy whatever while supplying the induction coils with alternating currents of pre-determined periodicity. The number of alternations can be regulated at will without interfering with the work or speed of the dynamo, so that if it should be desirable, the alternating circuit could even be regulated by automatically changing the rate of alternations to suit the desired output of the induction coils or converters.

The means of regulation are numerous. A compound-wound dynamo, without any mechanical regulating apparatus for keeping the difference of potential at the terminals of the induction coils uniform, and thereby permitting of the putting on and off of any number of lamps without reaction on the remaining lamps, and without waste of power for lamps not in use, has proved very successful. The writer has, however, found by experience that the most economical and most reliable regulation is effected by attaching an electrically-impelled governor to the prime mover itself, which regulates the consumption of steam or water-power in proportion to the work performed by, and drawn from, the dynamos.

The general idea of the Pfannkuche system of long distance distribution is shown in the accompanying illustration. From the brushes of the dynamo lead the wires, *a*, *a'*, of the circuit, A. One of these wires, *a*, terminates at a brush, *c*, and the other, *a'*, is branched and leads to two brushes, *c*, *c'*.

The alternating commutator, C, consists of three segments, *d* and *d'*, *d'*, mounted on the prolonged armature-spindle of the dynamo, and insulated therefrom and from each other. The middle segment, *d*, is made cylindrical at its centre, and has semi-cylindrical arms projecting therefrom in axially opposite directions and on diametrically opposite sides, and the outer segments, *d'*, *d'*, are made cylindrical at their ends, and each has a semi-cylindrical arm projecting axially and overlapping one of the like arms of the middle segment. The wire, *a*, brings positive currents to the brush, *c*, and segment, *d*, while the wire, *a'*, brings negative currents to the brushes, *c'*, *c'*, and segments, *d'*, *d'*. Two take-off brushes, *e*, *e'*, termed the "primary" brushes, are joined to the opposite terminals of circuit, B, and rest against the commutator, C, in such position that each shall contact alternately with the positive segment, *d*, and one of the negative segments, *d'*, and so that while one is in contact with the positive segment the other shall be in contact with the negative segment; hence when the commutator revolves, the line circuit, B, receives alternate positive and negative impulses, one to each revolution. In addition to the primary brushes, *e*, *e'*, there are also two secondary brushes, *f*, *f'*, which have a slight lead relatively to the primary brushes, and which are connected through branch wires, *g*, *g'*, to the respective wires of the line circuit, B.



If only the brushes, *e*, *e'*, were employed to take off the current from the alternating commutator, the circuit would be broken whenever either of these brushes passed over the insulation between the commutator sections—that is to say, twice to each revolution. This would occasion violent sparking at the commutator and heating of the armature coils, which would be ruinous to the dynamo and the commutator. This is prevented by using both primary and secondary brushes, and setting one as much in advance of the other as the width of the insulation, so that at the instant of crossing the insulation the leading brush makes contact with the positive segment before the other breaks contact with the negative segment, so that the circuit of the dynamo is never broken; but this arrangement alone would cause a short circuiting of the line at each crossing of an insulation, by the positive current flowing, for instance, into brush *e*, and thence back through brush *f* to the negative segment without traversing the line, B. Thus the entire resistance of the line would be cut out for an instant twice at each revolution, thus heating and injuring the dynamo. The resistance, R, prevents this result, not by preventing the short-circuiting from brush *e* to *f* and *e'* to *f'*, but by making this short circuit of equal resistance to the line, so that the dynamo feels no difference whether the current traverses the line or the short circuit. In this manner the circuit to the dynamo is in effect neither broken nor short-circuited, and no sparking or heating is caused. It is apparent that during the instant while the brushes, *e*, *f*, are on opposite sides of the insulation there will be no current supplied to the line circuit, B, but upon both brushes reaching the same segment of the commutator, C, the current to the line will be established in a direction reversed relatively to the preceding current. The rapidity of the alternation of the currents in the line circuit will depend upon the speed with which the alternating commutator is revolved. If it be fixed on the armature shaft, as shown in the illustration, it will revolve at the same speed as the armature.

It is evident, however, that the commutator may be mounted on a separate shaft and driven independently at any speed.

The secondary coils of the converters, E, E, may be joined in the local circuits in any desired way, according to the work which the several local circuits are expected to perform. In fig. 1 are shown three different methods—the circuit, L', including but one converter, the circuit, L^2, including three converters installed in multiple arc, and the circuit, L^3, including three converters installed in series. In either case the incandescent lamps, *l*, *l*, may be joined in multiple arc, or in any other arrangement.

As stated above, the writer prefers to render the machine self-regulating by using compound-winding.

In the use of rheostats, R, R', more or less energy expended in overcoming the resistance is wasted by being converted into heat. To economise this waste, there may be substituted for the rheostats one, two, or more converters, E', E', identical with those in the main line, except that the resistance of their primary coils may require to be somewhat different. In the illustration there are shown two converters, E', intercalated in multiple arc in each of the branch wires, *g*, *g'*. The resistance of the primary coils of these converters should be such that each branch circuit, *g*, *g'*, will have a resistance equal to or slightly exceeding that of the entire main line. The secondary coils of the converters, E', E', are connected in a local circuit, L^4, which will have the capacity of maintaining a few incandescent lamps, sufficient, probably, to light the generating station or some adjacent apartment.

By this system, therefore, the circuit, *a*, may be used to feed arc lamps or other apparatus requiring continuous current, while the other branch can be utilised for the transmission of alternating currents.

The Cable Steamer "Minia."—The Boston *Globe* published an interesting article on the 31st ult., giving an account, with neat pen sketches, of the cable steamer *Minia*, at the time in harbour at that city. Captain Trott, Mr. Hamiliton, the chief electrician, and Dr. Greer, of the *Minia*, were entertained by the New England Club on the 2nd inst.

ON THE DETERMINATION OF THE COEFFICIENT OF SELF-INDUCTION.

By E. C. RIMINGTON.

ON page 355 of the present volume there is an account given of a method for measuring self-induction, by MM. Ledeboer and Maneuvrier, taken from the *Comptes Rendus*. I propose to show how the formula which they employ may be obtained.

The following method of calculating the current through the galvanometer in a Wheatstone bridge when equilibrium is not obtained, in terms of the current in any one of the branches, will be found useful for this sort of work.

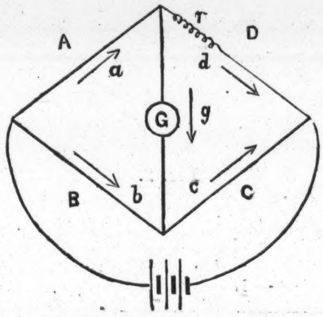


FIG. 1.

Suppose we have a Wheatstone's bridge, the resistances of the curves being A, B, C and D, as shown (fig. 1). Let A C = B D so that there is an exact balance. Introduce any resistance, *r*, into the arm, D, so as to upset the balance; and let the current in that arm be *d*. Then if *g* be the current in the galvanometer,

$$\mathrm{G} = \frac{d\,r}{\mathrm{D} + \mathrm{C} + \dfrac{\mathrm{G}\,(\mathrm{A} + \mathrm{B})}{\mathrm{G} + \mathrm{A} + \mathrm{B}}} \times \frac{\mathrm{A} + \mathrm{B}}{\mathrm{G} + \mathrm{A} + \mathrm{B}}$$

That is to say, we may treat $d\,r$ as an E.M.F. inserted in the arm, D, when there is a balance, and calculate the current through the galvanometer due to it by the laws of shunts, supposing the battery circuit to be broken. Since A C = B D the expression just given reduces to

$$\mathrm{G} = \frac{d\,r}{\mathrm{C} + \mathrm{D} + \dfrac{\mathrm{G}\,(\mathrm{B} + \mathrm{C})}{\mathrm{B}}}$$

This may be proved in the following manner. Let *a*, *b* and *c* be the currents in the arms A, B and C respectively.

Applying Kirchoff's laws, we obtain the following four equations :—

$$a = g + d \qquad (1)$$

$$b = c - g \qquad (2)$$

$$a\,\mathrm{A} + g\,\mathrm{G} - b\,\mathrm{B} = 0 \qquad (3)$$

$$d\,(r + \mathrm{D}) - c\,\mathrm{C} - g\,\mathrm{G} = 0 \qquad (4)$$

Solving for *g* and eliminating *a*, *b* and *c*, we obtain

$$\mathrm{G} = \frac{d\,(\mathrm{B}\,r + \mathrm{B\,D} - \mathrm{A\,C})}{\mathrm{A\,C} + \mathrm{B\,C} + \mathrm{G\,C} + \mathrm{G\,B}}; \text{ but } \mathrm{A\,C} = \mathrm{B\,D}.$$

Hence

$$\mathrm{G} = \frac{d\,r}{\mathrm{C} + \mathrm{D} + \dfrac{\mathrm{G}\,(\mathrm{B} + \mathrm{C})}{\mathrm{B}}}$$

which is the same expression as was obtained by treating $d\,r$ as an E.M.F. in D.

Now suppose we have a bridge (fig. 2). The arm, D, being a coil of coefficient of self-induction, L, the other arms possessing no self-induction. Adjust so that an ordinary balance is obtained when the battery circuit

C

is closed before the galvanometer circuit. Then A C = B D. Let the currents flowing in the branches D and C be x_0 and y_0 respectively. Now keeping the galvanometer circuit closed, break that of the battery, and let the current in D at some instant, t, after this be x. Then the E.M.F. of self-induction in D $= -L\frac{dx}{dt}$.

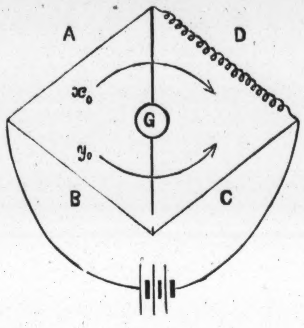


FIG. 2.

Therefore the current in the galvanometer

$$= \frac{-L\frac{dx}{dt}}{D + C + \frac{G(A + B)}{G + A + B}} \cdot \frac{A + B}{G + A + B}$$

$$= -L\frac{dx}{dt}\,p;$$

where p stands for

$$\frac{1}{D + C + \frac{G(A + B)}{G + A + B}} \times \frac{A + B}{G + A + B}.$$

Now if G be the total quantity of electricity which passes through the galvanometer, due to breaking the battery circuit,

$$G = -\int_0^\infty L\,p\,\frac{dx}{dt}\,dt = -L\,p\int_{x_0}^0 dx.$$

Since when the time is infinite* the current in D $= 0$

$$\therefore\ G = L\,x_0\,p.$$

The self-induction of the galvanometer is not taken into account, since the current through it begins and also ends with the value zero.

Now suppose we have a make and break arrangement which closes the battery circuit, closes the galvanometer circuit, breaks the former, then breaks the latter, and repeats this cycle of operations n times per second. The quantity which passes through the galvanometer during each cycle $= L\,x_0\,p$, and consequently the quantity which passes per second $= n\,L\,x_0\,p$.

Of course n must not be too large or the current will not have time to rise to its stable value x_0 when the battery circuit is made or to fall to 0 when the latter is broken. If the galvanometer we are employing is a mirror instrument and we obtain a deflection δ on it, then $n\,L\,x_0\,p = \gamma\,\delta$, where γ is the reduction factor of the galvanometer. Now remove the make and break arrangement and alter the resistance of the arm C by an amount r, and let the current through C become y_1 in consequence of this alteration. Let the deflection on the galvanometer be a. Then $r\,y_1\,p = \gamma\,a$.

Therefore

$$\frac{n\,L\,x_0}{r\,y_1} = \frac{\delta}{a}$$

$$L = \frac{r}{n} \cdot \frac{y_1}{x_0} \cdot \frac{\delta}{a}$$

but

$$\frac{x_0}{y_0} = \frac{B}{A} = \frac{C}{D} \text{ or } x_0 = y_0\frac{C}{D}$$

consequently

$$L = \frac{r}{n} \cdot \frac{y_1}{y_0} \cdot \frac{D}{C} \cdot \frac{\delta}{a}$$

If r the amount by which C is altered is small compared to C, y_1 will very nearly equal y_0 and

$$L = r \cdot \frac{D}{C} \cdot \frac{1}{n} \cdot \frac{\delta}{a} \text{ approximately.}$$

$$= r\frac{A}{B} \cdot \frac{1}{n} \cdot \frac{\delta}{a}$$

Professor Ayrton has recently devised a somewhat similar method, in which the cycle of operations of the make and break is as follows.

Galvanometer circuit made, battery circuit made, former broken, latter broken. The quantity passing through the galvanometer per sec. would be as before, $n\,L\,x_0\,p$. C is now altered by a resistance r when the make and break arrangement is still acting so as to bring the galvanometer index back to zero. It is necessary to know for what fraction of a cycle the battery and galvanometer circuits are closed simultaneously; suppose it to be $\frac{1}{m}$th.

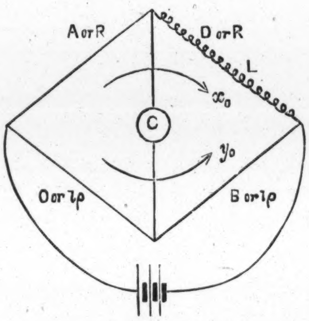


FIG. 3.

Then obviously

$$L = \frac{1}{m} \cdot r\,\frac{1}{n} \cdot \frac{A}{B}.$$

The advantage of this is that y_1 is the same as y_0, and it is a balance method.

MM. Ledeboer and Maneuvrier employ a slide wire bridge. They make $A = D = R$. Consequently $B = C = \rho\,l$ where $2\,l$ is the length of the slide wire and ρ is its resistance per unit of length. Instead of altering the resistance of C by an amount, r, they displace the slide through a length, ε.

Suppose the slider displaced towards the left. Then the resistance of B becomes $(l - \varepsilon)\,\rho$, and that of C $(l + \varepsilon)\,\rho$.

The resistance of C that would give an exact ordinary balance will consequently be $(l - \varepsilon)\,\rho$, but the actual resistance of $C = (l + \varepsilon)\,\rho$. Therefore the balance is upset by altering C by an amount $= 2\,\varepsilon\,\rho$.

We consequently have as before

$$\frac{n\,L\,x_0}{R + \rho\,l + \frac{G(R + \rho\,l)}{G + R + \rho\,l}} \times \frac{R + \rho\,l}{G + R + \rho\,l} = \gamma\,\delta$$

$$\frac{n\,L\,x_0}{2\,G + R + \rho\,l} = \gamma\,\delta, \text{ and } x_0 = y_0\,\frac{\rho\,l}{R}$$

$$\frac{n\,L\,y_0\,\rho\,l}{R\,(2\,G + R + \rho\,l)} = \gamma\,\delta.$$

Similarly

$$\frac{2\,\varepsilon\,\rho\,y_1}{2\,G + R + \rho\,(l - \varepsilon)} = \gamma\,a$$

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* The time of course need not be infinite in practice, as x will become practically zero in a very small fraction of a second in most cases.

$$\therefore \text{L} = \frac{2\,\varepsilon\,\text{R}}{l} \cdot \frac{1}{n} \cdot \frac{y_1}{y_0} \cdot \frac{2\,\text{G} + \text{R} + l\,\rho}{2\,\text{G} + \text{R} + (l - \varepsilon)\,\rho} \cdot \frac{\delta}{a}$$

If ε be small $y_1 = y_0$ approximately and $2\,\text{G} + \text{R} + l\,\rho = 2\,\text{G} + \text{R} + (l - \varepsilon)\,\rho$ approximately.

Therefore

$$\text{L} = 2\,\varepsilon\,\frac{\text{R}}{l} \cdot \frac{1}{n} \cdot \frac{\delta}{a}.$$

NOTE ON THE PERFORMANCE OF SOME DYNAMOS.

THE following table was constructed by D. C. Jackson, and published in the New York *Electrician and Electrical Engineer* with the view of comparing the results attained by the several prominent dynamo builders, principally English and American. The data were gathered wherever obtainable and reduced to uniformity. In most cases the authority for the original figures is given in the last column. Where this is omitted the results were gathered from measurements made on machines in the physical laboratory of Cornell University.

The importance to designers and those engaged in the study of the performance of dynamos of such a table, is thought to be sufficient apology for its publication.

Type of armature.	Machine.	Revolutions per minute.	Velocities.	I.	II.	III.	E.M.F.	Current.	Authority.
Siemens	Edison-Hopkinson	800	2100	·45	·013	·006	110	300	Kapp & Crompton.
"	Edison...	1750	2850	·312	·0065	·00018	125	40	
"	Weston	1000	1850	·234	·0077	·00024	150	20	Prof. Anthony.
"	Mather...	2750	3200	·260	·0049	·00010	125	40	
"	Wenström	460	2225	·114	·0031	·00025	110	190	*La Lumière Electrique.*
"	2½ inch...	3000	1875	·182	·0060	·00006	70	...	Prof. Anthony.
Gramme	Manchester (Mather & Platt)	1050	3300	·402	·0075	·00038	110	220	Kapp & Crompton.
"	Crompton	400	1620	·230	·0085	·00057	600	120	*Electrician*, London.
"	" (Plating)	700	2840	·336	·0070	·00048	110	490	"
"	Crompton	...	...	...	·0095	...	110	217	Crompton.
"	"	...	...	...	·0070	...	110	100	"
"	"	...	...	...	·0055	...	60	33	"
"	Elwell-Parker	...	...	...	·0080	...	110	460	"
"	" (4 pole) ...	...	...	...	·0065	...	...	...	Kapp.
"	" (2 pole) ...	...	...	...	·0045	...	...	...	"
"	Kapp	...	...	...	·0070	...	110	125	Kapp & Crompton.
"	Sperry	750	3150	·226	·0043	·00030	850	23	
"	Goolder & Trotter	765	2140	·132	·0038	·00017	56	285	*Electrician*, London.
"	" "	...	...	...	·0055	...	60	200	Kapp & Crompton.
"	Old Gramme	1000	2875	·109	·0023	·00011	200	25	Prof. Anthony.
"	Raffard-Breguet	1400	2750	·117	·0022	·00008	110	35	Crompton.
"	Ball ("Unipolar")	1380	3800	·132	·0016	·00010	470	8	*Electrician and Electrical Engineer*, N.Y.
"	"	1180	...	·113	...	·00010	710	8·2	" " "
"	Deprez (Paris-Creil)... ...	216	1475	·081	·0033	·00037	3000	9·9	Levy & Kapp.
Pacinotti	Phœnix	...	...	·290	·0058	·0006	110	380	Kapp & Crompton.
Brush	Brush	850	4670	·200	·0026	·00024	3000	9·5	
Thomson-Houston...	... ...	...	...	...	·0019	...	...	...	Kapp.

The first three columns of the table explain themselves. In the column marked velocities, are given periphery velocities in feet per minute.

The columns marked I, II and III, contain respectively the E.M.F. in volts generated by the machines per foot of armature wire, volts per foot of wire and per unit periphery velocity (1 foot per second), and volts per foot of wire and per one revolution per minute.

The dynamo with Siemens armature called "2½ inch" is a little machine with armature about 2½ inches in diameter and 6 inches long. It is one of two such machines built by Prof. Anthony for experimental purposes. The excellent performance of so small a machine is explained by the excellence of its construction. Its field-magnets are solid forgings of Swedish wrought iron and the armature core consists of thin insulated plates of soft iron.

The "old Gramme" dynamo was built in the laboratory in 1874, by Prof. Anthony, immediately on learning of Gramme's success. It has been in constant use ever since for experimental purposes in the laboratory. Its field-magnets have wrought iron limbs and cast iron pole pieces and end yokes. A comparison of its performance with that of the Raffard-Breguet, one of the latest French dynamos, is instructive.

The machine of Deprez given in the table is the generator in the final Paris-Creil experiments.

THE ELECTRIC LIGHT AT BOURNEMOUTH.

LAST week in honour of the successful result of their electric lighting experiments at Bournemouth, which culminated in the illumination of the pier on Easter Monday, Messrs. Mortimer, Shepherd and Co., gave a dinner to many influential inhabitants at the Belle Vue Hotel, the front of which was rendered exceedingly brilliant by a lamp of 1,000 C.P., while the room in which the banquet took place was lighted with incandescent lamps. In the course of the post-prandial speeches, attention was directed to the fact that the advance of electric lighting has been considerably hampered in the past by Government restrictions, having the effect of deterring capitalists from investing their money in such enterprises. All that electricians required was a fair field and no favour. The chairman (Mr. Rebbeck), in proposing the toast of the electric lighting firm, said that Bournemouth owed to Messrs. Mortimer and Shepherd a deep debt of gratitude, because they had given the inhabitants, entirely at their own expense, an opportunity of witnessing the advantages of electric lighting. He understood that further experiments were to be made, these being exhibitions of the Pilsen and Thomson-Houston arc systems and of incandescent lighting. If the idea had been to carry the wires through the streets on poles, he should have strongly opposed the electric lighting scheme, but Mr. Shepherd had effectually disposed of any such objection by saying that the wires could be run underground. Mr. Shepherd had also promised that the expense should not exceed that of gas by five per cent., and if those were to be the terms, he should have no objection to adopting the electric light in his own shop. Considering the manifest advantages which electricity possessed over gas, its general use could not fail to be of great advantage to the town. Mr. Shepherd, in response, said that his firm was not wedded to any particular system, and would leave the people of Bournemouth to say which they liked best. He quite agreed that it would be nothing short of sacrilege to destroy the distinctive features of Bournemouth, but the placing of wires underground would involve a great outlay. They did not ask the Commissioners to bind themselves to anything until they had been clearly shown the value of electricity, and he believed that after that, the town generally would recognise the great advantage of adopting it.

On the same night there was a display of the electric light outside Newlyn's Exeter Hotel, which attracted considerable public attention. For some weeks past, an example of the suitability of electricity for domestic lighting has been afforded at the shop of Mr. Fippard, and on one occasion, Messrs. Mortimer, Shepherd and Co. displayed outside their station in Orchard Street, an arc lamp of exceptional power, which illuminated the whole neighbourhood. By means of these liberal experiments, public opinion is being rapidly educated in the right direction.

ON THE MAGNETISATION OF IRON IN STRONG FIELDS.*

By Prof. J. A. EWING, B.Sc., F.R.S.E., University College, Dundee, and Mr. WILLIAM LOW.

Communicated by Sir W. THOMSON, Knt., LL.D., F.R.S.

THE behaviour of iron and steel when subjected to very strong magnetising forces is a matter of considerable practical and very great theoretical interest, especially from its bearing on the molecular theory of magnetisation, which assigns an upper limit to the intensity of magnetism that a piece of iron can acquire, and even suggests that the metal may become diamagnetic under the influence of a sufficiently great force. All experiments hitherto made, by magnetising iron in the field of an electric solenoid, have shown that the intensity of magnetism, $\mathfrak{I}$, as well as the induction, $\mathfrak{B}$, is increasing with the highest values actually given to the magnetising force, $\mathfrak{H}$. It is scarcely practicable, however, to produce by the direct action of a magnetising solenoid, a field whose force exceeds a few hundreds of C.G.S. units.

To refer to a few recent experiments of this class:—In experiments by one of us† on the magnetisation of long wires, the highest value of $\mathfrak{H}$ applied to iron was about 90, and this gave an induction, $\mathfrak{B}$, of 16,500 in a soft iron wire. In Dr. Hopkinson's experiments‡ a force of 240 gave 19,840 for the induction in a bar of mild Whitworth steel, and 18,250 in a bar of wrought iron.§ The corresponding values of $\mathfrak{I}$ are 1,563 and 1,437 respectively. Probably the highest magnetisation reached in any experiments of this class already published is that found by Mr. Shelford Bidwell || in his experiments on the tractive force between the halves of a divided ring electro-magnet. For a force $\mathfrak{H}$ of 585 he gives 19,820 as the value of $\mathfrak{B}$ (calculated from the tractive force) in a wrought iron ring. The corresponding value of $\mathfrak{I}$ is 1,530.

With cast iron, Dr. Hopkinson found (in a sample of grey iron) 10,783 for the induction produced by a force of 240. The corresponding value of $\mathfrak{I}$ is 841.

In the space between the pole pieces of a strong electro-magnet we have a field of force of much greater intensity than it is practicable to produce by the direct action of the electric current. This field is not well adapted for experiments whose object is to determine with precision the relation of magnetisation to magnetising force, on account of the distortion which it undergoes when the piece of iron to be magnetised is introduced into it. It is, however, well suited for experiments whose object is to determine how much magnetism the metal can be forced to take up.

For this purpose it is of course necessary that the cross section of the test piece should be much smaller than the area of the pole piece faces. In the following experiments the electro-magnet consisted of a pair of vertical limbs 25 cm. long, with cores 5 cm. in diameter, joined at the bottom by a horizontal yoke, and furnished on the top with pole pieces, made of soft hammered scrap iron, in the form of rectangular blocks with plane faces, whose distance from each other could be adjusted at will. The faces were 5·25 cm. square. The magnet was wound with wire large enough to permit a current of about 27 ampères to be used for a short time. In the earliest experiments the test piece to be magnetised was a round cylinder of soft iron, with flat ends 0·34 cm. in diameter and 1·3 cm. long. This was covered with an induction coil, consisting of a single layer of fine wire, which extended over the whole length of the piece. It was placed length-wise in the centre of the field, with the pole pieces just touching its ends, and the field magnet was excited. The test piece was then suddenly withdrawn, while the transient current produced in the induction coil was measured by a ballistic galvanometer connected to the induction coil by long leading wires, which were twisted together throughout their whole length. Very few experiments were made with test pieces of this form, for it was found that they gave by no means an exceptionally high value for the magnetic induction. This is to be ascribed to the fact that the ends of the cylinder, which were in contact with the pole pieces, necessarily shared that value of the induction which existed in the part of the pole piece faces which they touched, and this comparatively low induction in and near the ends of the cylinder neutralised the much higher value in the middle portion. The induction coil, being wound from end to end of the bar, gave a mean value for the whole length. To obtain higher values, it was obviously necessary to restrict the measurement of the induction to the middle portion, where the induction was greatest; and, further, it was desirable to furnish the bar with conical or some form of spreading ends, which would present an easy path for the lines of induction to converge towards the central neck. Accordingly, test pieces were turned of the form and dimensions of Sample A, shown in fig. 1, where the bobbin is sketched in place between the pole pieces. These were wound along the whole length of the narrow central neck with an induction coil consisting of a single layer of No. 36 S.W.G. silk-covered wire. In Sample A the diameter of the iron neck was 0·923* cm., and the diameter measured to the middle of the thickness of the wire forming the induction coil was 0·9495. Hence there was but little space, outside the section of the iron, enclosed by the coil; and the small amount of magnetic induction in this non-ferrous space was allowed for by a method to be explained below.

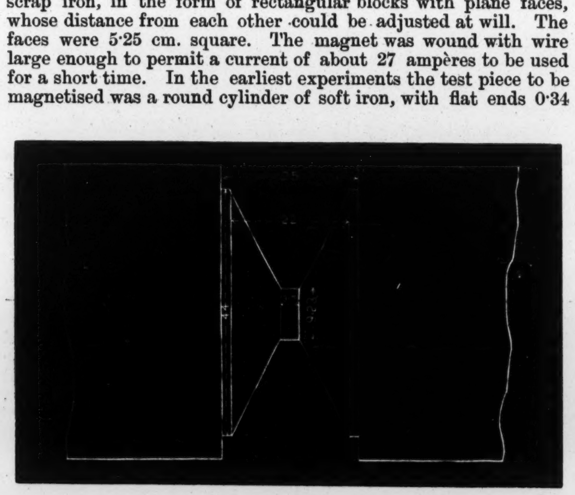

FIG. 1.

In test pieces of the form of Sample A the loss of magnetism observed on suddenly withdrawing the piece from its place between the pole pieces of the field-magnet, is less than the whole magnetism by the small but somewhat uncertain quantity of residual magnetism which the piece retains. To avoid this source of uncertainty another form of test piece was used, which is shown in fig. 2, Sample B. Here the bobbin has its conical ends rounded at the base to form portions of a circular cylinder, and the pole pieces are hollowed to correspond. The bobbin can now be turned completely round about a central axis at right angles to the paper, so that the direction of its magnetism is reversed, and half the ballistic effect of the reversal measures the magnetic induction. This method was used in the greater number of the observations. Again, by merely withdrawing the bobbin from the field, and comparing the effect of this withdrawal with half the effect of reversal, an estimate was arrived at of the amount of error to which the former experiments were subject on account of residual magnetism.

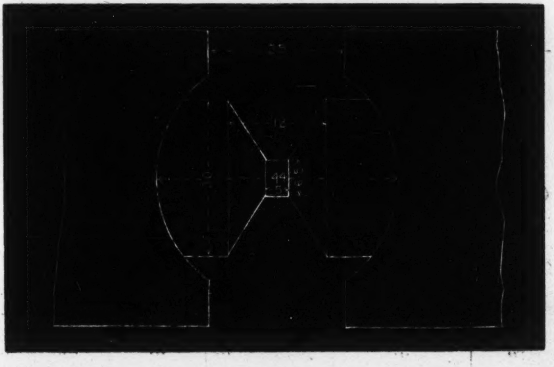

FIG. 2.

To determine the intensity of the magnetic field in the space immediately surrounding the narrow neck in which the greatest induction occurred, a small quantity of wire was wound over the first induction coil, to form a distance piece, and on the top of that a second induction coil was wound, the second coil, like the first, consisting of a single layer of very fine wire. The space between the two coils was accurately determined. When the test piece was reversed or drawn out of the field the operation was in each case performed several times, and two groups of observations were recorded, one giving the induction in the inner coil, and the other the induction in the outer coil; the difference, of course, served to determine the field in the space between the coils. When this field was known, it was easy to correct for the induction in the non-ferrous space enclosed by the inner coil.

Three kinds of wrought iron were tested; soft hammered scrap, Swedish iron, and Lowmoor iron. The hammered scrap proved less susceptible than the other two, and was not used in the final experiments, which were made with test pieces of the form of Sample B. Pieces of cast iron were also tested, in forms resembling both A and B.

To determine in absolute measure the value of the ballistic effects, a large earth coil was kept in circuit with the induction coil and galvanometer, and was turned over in either the vertical or horizontal earth field at the beginning, and again at the end of each group of observations. To avoid the possibility of error in

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* Read before the Royal Society, March 24th, 1887.

† Ewing, "Exp. Res. in Magnetism," *Phil. Trans.*, 1885, Part II.

‡ J. Hopkinson, "Magnetisation of Iron," *Phil. Trans.*, 1885, Part II.

§ J. and E. Hopkinson have observed an induction of 20,000 in the core of a dynamo armature, under a force estimated at 740 (*Phil. Trans.*, 1886 Part I., p. 355.)

|| S. Bidwell, "On the Lifting Power of Electro-magnets and the Magnetisation of Iron, "Roy. Soc. Proc.," vol. 40, 1886, p. 486.

* In the original drawings the decimal in figures 1 and 2 appears to have been put in the wrong place.—EDS. ELEC. REV.

this important particular, two separate earth coils of entirely different dimensions were employed, and the galvanometer constant was determined independently by means of both, with results which were in excellent agreement. The values of the induction stated below are worked out on the basis that the horizontal force in the grounds of University College, Dundee, at a place sufficiently removed from local magnetic influence, is 0·160 in C.G.S. units.

The following experiments are representative of a considerably larger number :—

Lowmoor iron, annealed before turning the bobbin from a forged bar. Sample B, of shape and dimensions shown in fig. 2. Diameter of iron neck = 0·65 cm. ; length = 0·44 cm. Diameter to middle of inner induction coil, 0·6765 cm. Diameter to middle of outer induction coil, 0·9364 cm.

Area of section of iron (s_1) = 0·3318 sq. cm.

Area of space to be corrected for under inner induction coil (s_2) = 0·0276 sq. cm.

Area of space between inner and outer coil (s_3) = 0·3293 sq. cm.

Number of turns on inner induction coil = 16; number on outer coil = 12.

In the following table D_1 is the throw of the ballistic galvanometer given by the inner coil when the test-piece was turned round, and D_2 is the throw given by the outer coil. X_1 and X_2 are the corresponding *total* inductions in C.G.S. units. The difference of these, given in the fifth column, when divided by s_3, is the intensity of field or magnetic force per sq. cm., in the space immediately surrounding the iron. This is given in column VI. Multiplying it by s_2, we have the correction to be subtracted from X_1, which is given in column VII. Finally, by dividing the corrected value of X_1 by the section of the iron s_1, we find $\mathfrak{B}$, the magnetic induction in the iron per sq. cm. Column IX gives the current in the field-magnet coils in ampères.

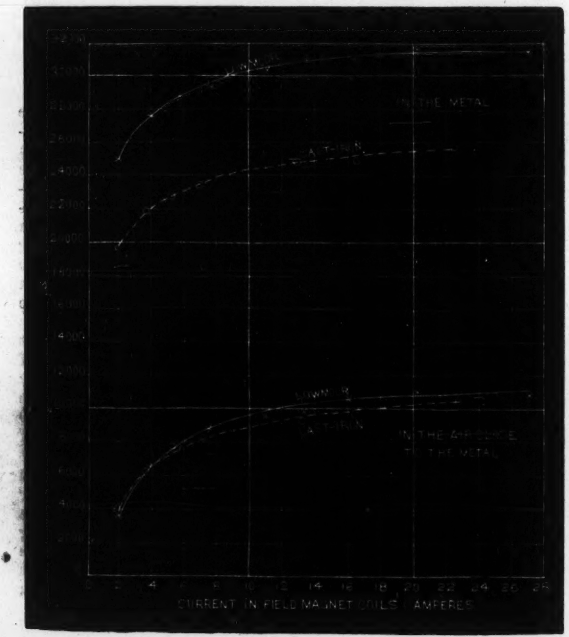

FIG. 3.

LOWMOOR WROUGHT IRON: SAMPLE B.

I. D_1.	II. X_1.	III. D_2.	IV. X_2.	V. $X_2 - X_1$.	VI. Field round iron neck per sq. cm.	VII. Correction to be subtracted from X_1.	VIII. $\mathfrak{B}$.	IX. Current in field magnets, ampères.
127	8,295	109	9,490	1195	3,630	100	24,700	1·98
143	9,340	132½	11,540	2200	6,680	180	27,610	4·04
150	9,800	142	12,370	2570	7,800	220	28,870	5·81
153	9,990	148	12,890	2900	8,810	250	29,350	7·60
157½	10,280	154	13,410	3130	9,500	260	30,200	11·0
160	10,450	157	13,670	3220	9,780	270	30,680	13·5
161	10,520	160	13,930	3410	10,360	290	30,830	16·2
164	10,710	164	14,280	3570	10,840	300	31,370	21·6
165	10,780	166	14,460	3680	11,180	310	31,560	26·8

In another test of Lowmoor iron, conducted in the same way, a still higher value of $\mathfrak{B}$ was reached, namely, 32,880. This is the highest induction that has been recorded in these experiments.

A similar experiment with a piece of Swedish wrought iron, of the form and dimensions shown in fig. 2, gave 32,310 for the greatest value of $\mathfrak{B}$, the magnetic force in the ring of space surrounding the iron neck being then 11,250.

The amount of residual magnetism retained by a Lowmoor sample of this form (Sample B) was determined by comparing the effect of withdrawing the test piece with the effect of reversing it. The results showed that within the range of magnetic force used in these experiments, namely, from about 4,000 to 11,000 C.G.S. units, the residual magnetism is nearly constant. Its mean value in a number of determinations was :—

For Lowmoor iron, residual induction, $\mathfrak{B}_r$ = 510 per sq. cm.

For Swedish iron, residual induction, $\mathfrak{B}_r$ = 500 per sq. cm.

These results showed that pieces of the form of Sample B (fig. 2) retained only a small part (less than 1/60) of their greatest induction when withdrawn from the field. The proportion of residual to greatest induced magnetism in samples of the form A (fig. 1), is probably not very different from this.

In the following experiment a bobbin of annealed Swedish iron, of the size and shape shown in fig. 2, was tested by withdrawing it from the field. The columns of the table have the same meaning as before, except that the quantity in column VIII., now headed $\mathfrak{B} - \mathfrak{B}_r$, is not the whole induction per sq. cm., but that part of the induction which disappeared when the test-piece was withdrawn from the field. In this case the section of the iron was the same as before, but the space between the inner and outer induction coils (s_3) was 0·308 sq. cm. There were fourteen turns in the inner coil and twelve in the outer.

SWEDISH WROUGHT IRON: SAMPLE B.

I. D_1	II. X_1	III. D_2.	IV. X_2.	V. $X_2 - X_1$.	VI. Field round iron neck per sq. cm.	VII. Correction to be subtracted from X_1.	VIII. $\mathfrak{B} - \mathfrak{B}_r$.	IX. Current in field magnets, ampères.
125·5	9,290	131·5	11,350	2060	6,690	180	27,460	4·08
134·5	9,950	147·0	12,690	2740	8,900	250	29,230	7·77
139·5	10,320	153·5	13,250	2930	9,510	260	30,320	10·9
141·5	10,470	157·0	13,550	3080	10,000	280	30,710	14·2
143·5	10,620	160·0	13,810	3190	10,360	290	31,130	16·5
144·0	10,660	162·0	13,990	3330	10,810	300	31,220	18·9
145·5	10,770	163·5	14,120	3350	10,880	300	31,560	22 9
147·0	10,800	166·0	14,330	3450	11,200	310	31,860	26·5

The residual magnetism may be corrected for by adding 500 as the value of $\mathfrak{B}$ to each of the numbers in column VIII. We then obtain for the highest induction $\mathfrak{B}$ the value 32,360.

The following results relate to test-pieces of the form and size shown in fig. 1 :—

Swedish wrought iron. Form of Sample A. Section of iron neck = 0·669 sq. cm. Section to middle of induction coil = 0·708 sq. cm. Loss of induction per sq. cm. tested on withdrawing the bobbin ($\mathfrak{B} - \mathfrak{B}_r$).

Current in field magnets, ampères.	$\mathfrak{B} - \mathfrak{B}$
3·92	27,550
7·48	29,420
11·3	30,240
14·0	30,460
17·9	30,960
20·1	31,180
20·4	31,290

These figures agree very well with those in the preceding table, which related to another sample of different form cut from the same bar. Probably 500 is in this case also a fair estimate of the residual induction, and by adding that to the values given above we arrive at probable values of $\mathfrak{B}$.

Lowmoor wrought iron. Form of Sample A. Dimensions as above. Current in field magnets = 20·4 ampères. Loss of induction on withdrawing the bobbin ($\mathfrak{B} - \mathfrak{B}_r$) = 31,660. Allowing for the residual magnetism, this gives an induction exceeding 32,000.

Soft Hammered Scrap. Form of Sample A. Dimensions as above.

Current in field magnets.	$\mathfrak{B} - \mathfrak{B}_r$
20·4	31,230
26·2	31,520

The remaining experiments relate to cast iron. The following results are for a sample of the form shown in fig. 2, except that the neck was of considerably larger diameter, namely, 0·962 cm. The sample was tested by turning it end for end in the magnetic field.

Section of neck = 0·727 sq. cm.
Section within middle of inner induction coil = 0·767 sq. cm.
Space to be corrected for = 0·040 sq. cm.
Section within middle of outer induction coil = 1·195 sq. cm.
Space between coils = 0·328 sq. cm.

CAST IRON.

x_1.	x_2.	$x_1 - x_2$.	Field round iron neck per sq. cm.	Correction to be subtracted from x_1.	$\mathfrak{B}$.	Current in field magnets, ampères.
14,450	15,730	1280	3,900	160	19,660	1·97
16,200	18,300	2100	6,400	260	21,930	3·75
16,910	19,440	2530	7,710	310	22,830	5·38
17,420	20,070	2650	8,080	320	23,520	7·08
18,240	21,260	3020	9,210	370	24,580	13·15
18,490	21,670	3180	9,700	390	24,900	16·9
19,030	22,510	3480	10,610	420	25,600	22·6

Another set of readings were taken with this sample at the same time, by drawing it suddenly out of the field, in order to determine the residual induction. The results showed that throughout the range of magnetic forces employed here, the residual induction had a nearly constant value of 400 C.G.S. units per sq. cm.

A bobbin of cast iron of a form resembling Sample A, fig. 1, was also tested by drawing it out of the field. The results were in close agreement with those given above for the other sample.

In fig. 3 the general results for Lowmoor wrought iron (Sample B) and cast iron are shown by curves which give the relation (1) of the induction $\mathfrak{B}$ within the metal neck to the current in the field-magnet coils, and (2) of the induction or magnetic force in the space immediately surrounding the neck to the current in the field-magnet coils. The full lines are for the Lowmoor forging, and the broken lines are for cast iron. The field produced by a given current is (at its higher values) rather less strong in the case of cast iron, probably because the larger size of the cast iron neck allowed a greater portion of the whole induction from pole to pole to find its way through the metal. (Compare x_1 for cast iron and for Lowmoor.)

I.—LOWMOOR WROUGHT IRON.

Outside field.	$\mathfrak{B}$	$\frac{\mathfrak{B} - \text{outside field}}{4\pi}$	$\frac{\mathfrak{B}}{\text{outside field.}}$
3,630	24,700	1680	6·80
6,680	27,610	1670	4·13
7,800	28,870	1680	3·70
8,810	29,350	1630	3·33
9,500	30,200	1650	3·18
9,780	30,680	1660	3·14
10,360	30,830	1630	2·98
10,840	31,370	1630	2·89
11,180	31,560	1620	2·82

II.—SWEDISH WROUGHT IRON.

Outside field.	$\mathfrak{B}$.	$\frac{\mathfrak{B} - \text{outside field}}{4\pi.}$	$\frac{\mathfrak{B}}{\text{outside field.}}$
6,690	27,960	1700	4·18
8,900	29,730	1660	3·34
9,510	30,820	1700	3·24
10,000	31,210	1690	3·12
10,360	31,630	1700	3·05
10,810	31,720	1670	2·94
10,880	32,060	1690	2·95
11,200	32,360	1690	2·90

III.—CAST IRON.

Outside field.	$\mathfrak{B}$.	$\frac{\mathfrak{B} - \text{outside field}}{4\pi.}$	$\frac{\mathfrak{B}}{\text{outside field.}}$
3,900	19,660	1250	5·04
6,400	21,930	1240	3·42
7,710	22,830	1200	2·96
8,080	23,520	1230	2·91
9,210	24,580	1220	2·67
9,700	24,900	1210	2·57
10,610	25,600	1190	2·46

The magnetic force within the metal ($\mathfrak{H}$) differs from the field in the surrounding space by an amount which cannot be estimated without a knowledge of the distribution of free magnetism on the pole pieces and conical faces of the bobbin. It appears probable that with the dimensions of the various parts used in these experiments, the magnetic force within the metal is less, but not very greatly less, than the outside and closely neighbouring field. In the absence of any exact knowledge of $\mathfrak{H}$, it is interesting to examine the relation of $\mathfrak{B}$ to the outside field. Thus, ($\mathfrak{B}$ – outside field)/4π gives a quantity which is probably not much less than the intensity of magnetism $\mathfrak{I}$. The values of this quantity for Lowmoor wrought iron, Swedish wrought iron, and cast iron are stated below. In the case of the Swedish iron the values of $\mathfrak{B} - \mathfrak{B}_r$ given in the previous table for that metal have had 500 added to allow for the residual magnetism. Again, the quantity $\mathfrak{B}$/outside field is probably not much less than the magnetic permeability μ: its values also are given below.

Fig 4 shows by curves the relation of $\mathfrak{B}$ to $\mathfrak{B}$/outside field for Lowmoor iron and for cast iron, in the manner introduced by Rowland for showing the relation of $\mathfrak{B}$ to μ. The curves have the same kind of inflection that a curve of μ and $\mathfrak{B}$ begins to have when the magnetising force is raised sufficiently high.* The range through which the permeability of iron may vary is well shown by comparing the values reached here (probably in the extreme case less than 3) with the value 20,000, which was found by one of us in the case of a soft wire exposed to a very small magnetising force and kept at the same time in a state of mechanical vibration.†

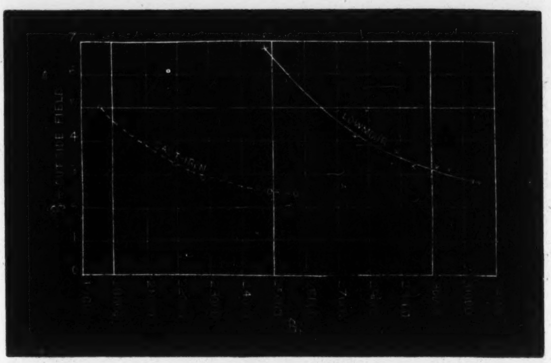

FIG. 4.

The quantity ($\mathfrak{B}$ – outside field) /4π is nearly constant in the Swedish iron, but diminishes with increased induction in the Lowmoor iron and in the cast iron. If the outside field were an accurate measure of $\mathfrak{H}$, this would mean that in the two metals last named $\mathfrak{I}$ had passed a maximum, and the process of diamagnetisation which the Ampère-Weber molecular theory of magmitism anticipates had set in. But the uncertainty which attaches to the value of $\mathfrak{H}$ prevents this conclusion from being fairly drawn from these experiments. A slight excess in the mean value of $\mathfrak{H}$ within the metal neck over the value of $\mathfrak{H}$ in the space contiguous to the neck would suffice to convert the apparent decrease of $\mathfrak{I}$ into an increase, with increasing values of $\mathfrak{B}$. So far as these results can be said to bear upon the point in question, they rather support the idea that the intensity of magnetism $\mathfrak{I}$ becomes and remains a sensibly constant quantity when the magnetising force is raised to very high values. This maximum of $\mathfrak{I}$ appears to exceed 1,700 in wrought iron and 1,250 in cast iron, and it does not appear likely that any increase of magnetising force will bring the intensity of magnetism in cast iron to a value equal or nearly equal to that which wrought iron is capable of acquiring. It is scarcely necessary to add that our experiments give no support to the suggestion that there is a maximum of the induction $\mathfrak{B}$. The value of $\mathfrak{B}$ capable of being reached by the method we have employed depends mainly on the scale of the experiments. Larger field-magnets with pole pieces tapering to a narrow neck should yield values of $\mathfrak{B}$ greatly in excess even of those we have observed.

The experiments will be continued and various qualities of steel will be examined with the following modification in the apparatus:—The pole pieces will themselves be turned, at the ends which face each other, into cones with flat ends, between which the test piece in the form of a round cylinder will be inserted. The induction will be measured in the neighbourhood of a medial transverse plane only, and the value of the field outside the iron will be determined in this plane at various distances from the axis. Since there is no free magnetism in the iron bar in the medial plane, the magnetic force within the metal is continuous with the force in the surrounding space, and a curve showing the relation of the magnetic force at various points outside to the distance from the axis should admit of being produced so as to give a good approximation to the magnetic force within the metal. If this can be successfully accomplished, the value of the *isthmus* method of examining the magnetisation of iron will be greatly enhanced.

[Dr. Hopkinson informs me that he experimented by what we have called the "isthmus" method nearly three years ago, but gave it up from uncertainty about the induction which took place through the coil but not through the iron. In the present experiments this difficulty has been avoided mainly by using larger bobbing with a single layer of fine wire for induction coil. I am indebted to Dr. Hopkinson for the suggestion (soon to be put in practice) that the "isthmus" method should be applied to the manganese steel whose non-magnetic quality under ordinary conditions has been already commented on by himself as well as by Mr. J. T. Bottomley and Prof. Barrett. In connection with the values of 𝔅 reached by other observers, Prof. J. J. Thomson informs me that in some recent experiments by himself and Mr. H. F. Newall on the effect of cutting a magnet at right angles to the lines of force, an induction of 28,000 was found on one occasion.—J. A. E.]

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* This feature of the curve of μ and $\mathfrak{B}$ was not noticed by Rowland himself, who applied to his curve an empirical formula which fails to take account of it. It has, however, been noticed by several later observers (Fromme, "Wiedemann, Annalen," vol. 13, p. 695; Ewing, *loc. cit.*, p. 574; Bidwell, *loc. cit.*, p. 495).

* Ewing, *loc. cit.*, p. 567.

ELECTRIC LOCOMOTION.*

By A. RECKENZAUN.

No less than seven papers bearing upon the subject of the transmission of power by means of electricity have been read and discussed in this room within the last six years, Mr. Alexander Siemens, in 1881, taking the lead with an interesting address on "Electric Railways and the Transmission of Power by Electricity." This gentleman again favoured us in April, 1883, with an account of the great progress made during an interval of two years by Messrs. Siemens on the Continent, and he was followed at the same meeting by Dr. Edward Hopkinson, who presented an equally interesting communication on "The Portrush Electrical Railway." A few weeks later, Prof. George Forbes enlightened us with his most instructive lecture, entitled "Electricity as a Motive Power."

The late Prof. Fleeming Jenkin described, in 1884, an ingenious system of electric haulage called "Telpherage." During the same session, I made an attempt to explain the principle of applying electricity to the propulsion of "electric launches;" and last year, on the 22nd of January, Captain Douglas Galton, in his excellent paper on the "Results of Experiments on Mechanical Motors for Tramways at the Antwerp Exhibition," presented us with most valuable data concerning mechanical traction.

Yet, with all this vast amount of useful information before me, I have had little difficulty in selecting a point of view from which we may regard the subject to-night. The ground has been so well prepared on the various occasions enumerated, that there is now no necessity on my part to explain the principles involved in generating electricity and transmitting or converting the same for the purposes of electric locomotion. I therefore beg to offer the following observations as an appendix to the aforementioned papers, and to bring forward fragmentary descriptions of details of construction, also, where possible, working expenses and the amount of traffic on several electric tramways in this country and on the continent of Europe.

It has become the custom to distinguish between different systems of electric tramways, by the methods adopted in conveying the energy generated in the stationary dynamo to the electromotor which moves along with the car, and we may divide these systems as follows:—

1. The system in which the ordinary rails serve as conductors of the electric current, the axles of the car being insulated from the wheel tyres, and circuit with the motor established through a contact brush, or roller, sliding along the rails.
2. The system of overhead conductors. In this a number of strong posts are placed alongside the line, carrying slotted tubes or rods of metal, upon which sliding or rolling contact carriages are placed, and these communicate electrically with the car motor by means of a flexible cable.
3. The system of the "third-rail conductor," which is placed between the ordinary rails, or alongside the line, on insulators a short distance above ground.
4. The system of underground conductors enclosed in a channel, with a central slot for the free passage of the contact carriage.
5. The system of well-insulated underground conductors, with no channel, temporary contact being made through short sections of surface contact rails with the motor on the car during its passage over that particular section on which the car is moving at the time.
6. The system of applying secondary batteries within the car, carrying stored energy along with it, whereby the vehicle is rendered independent, so that it can run on any line of suitable gauge without alteration to the roadway.
7. The system of applying secondary batteries to a separate locomotive, which hauls an ordinary car or cars behind it.

Members of the Society of Arts, and readers of the technical journals, will recollect that on the 12th of May, 1881, an electric tramway between Lichterfeld station of the Berlin-Anhalt Railway and the Central Military School, a distance of one and a-half miles, was opened to the public. Not many weeks ago, I visited that district near Berlin in order to obtain some information concerning the working of the tramway, and I have the satisfaction of telling you that the electric cars, although in continuous operation for a period of six years, have exhibited no signs of deterioration, and there have been no mishaps worth mentioning. The rails, which serve as conductors, are laid along the high road principally, and a small portion of the line runs across fields. No special means of insulation were used, the rails being fixed in the ordinary way to wooden sleepers, laid transversely along one side of the road. Electrical contact between sections of rails is effected through flexible iron loops. With such short lines of comparatively little resistance, the electromotive force can be kept low, and, in the case of the Lichterfeld line, it amounts to only 90 or 100 volts, and is therefore not dangerous to the touch of man or beast. Several roads cross this line, and at such crossing places the rails are cut out of circuit by means of underground cables; contact boxes, with switches, are placed near the crossings, in order that the current may be sent through these insulated sections of rails if requisite. The house containing the steam engines and generating dynamos is situated close to the rails, but at a distance of about one-third of a mile from the Lichterfeld terminus. There are two steam engines, each of 6 horse-power nominal, and two Siemens dynamos; one is a horizontal engine, and this is generally in use when one car only is running; and the other is a Dolgourouki high-speed rotary engine, coupled direct to the dynamo, running at 700 revolutions per minute; this latter comes into requisition when the traffic demands the second car. According to the printed time-table, one car makes twenty-four journeys a day, between 7.47 a.m. and 11.21 p.m.

I have not been able to ascertain the working costs of this line, but it must be very low, since the engines and dynamos are in the house, which also contains the pumping machinery of the district waterworks; one engineer and one stoker attend to both the hydraulic and the electric apparatus, the same boiler serving both purposes, and these men find time to attend to minor repairs. On the car is a driver, but no conductor. Each vehicle carries 24 passengers; it weighs, when empty, but including motors and gearing, 3·2 tons. The average speed is 12 miles an hour, and one journey occupies nearly eight minutes, for which a passenger has to pay 20 pfennige; this is nearly 2½d. About 100,000 passengers are carried annually. One remarkable fact in connection with this successful enterprise is, that the cars, although identical in every other respect, are fitted with different kinds of gearing, with the view of ascertaining practically the efficiency of each. Those who have devoted their attention to the subject of electric locomotion are well aware that the choice of the mechanical transmission between the fast running motors and the comparatively slow motion of car wheels is one of considerable difficulty. To the uninitiated it seems the easiest thing in the world to reduce, for instance, 800 revolutions of one shaft to 80 revolutions of another shaft; but when the arrangement has to be applied to a tramcar, where space is limited, noise objectionable, dirt and dust in abundance, then one obstacle after another seems to appear. This branch of our subject really deserves a separate and exhaustive treatment, if we had sufficient time at our disposal; but as I have chosen such a sweeping title, I shall have to confine my remarks on mechanical gearing within very narrow limits. With regard to the Lichterfeld cars, the one which ran some 13,000 miles per annum, or nearly 76,000 miles since the opening of the line, is fitted with a peculiar kind of transmission, little known in this country. The motor, in this case, is fixed underneath the floor, in the middle of the car, with the shaft of the armature parallel to the axles. The motor shaft carries a pulley of small diameter with 27 V-grooves cut upon its rim; one of the car axles has a large pulley with 13 grooves, and the other car axle carries a similar pulley upon which 14 V-grooves are cut. The wheel-base is 5 feet 9 inches, consequently the centres of the pulleys are only 2 feet 10½ inches apart. Within the grooves run 27 cords of spiral steel wires, so that one driving axle is worked by 13 and the other by 14 cords from one common pulley on the motor. The steel cords, a sample of which is on this table, are made of a pair of wires wound closely upon a mandril rather less than one-eighth of an inch in diameter; the mandril is afterwards withdrawn, so that a stiff and yet flexible spiral is left with an external diameter of barely $\frac{7}{32}$ of an inch. The ends of each spiral cord have steel eyes screwed into them and soldered, and when placed in position these eyes are connected by a steel wire link. One curious fact about these spirals is, that they stretch very little, and experiments have shown that one single cord will suffice to draw the empty car on a clean level line, whilst eight cords were used for a car full of passengers; therefore, with 27 there is a good margin of safety. As may be expected, this mechanical arrangement works without noise or vibration. Some experience is required in putting the cords upon the pullies, for, I am told, if stretched too tightly, they are liable to break at the joints, and if too loose they will slip when starting; but with careful attention on the part of the engineer in charge, very few breakages occur. There are only moderate gradients on this line; the worst, one of 1 in 100, is about 460 yards in length; the question, therefore, remains whether this kind of gearing would suit a more difficult line. The second spare car belonging to this tramway is fitted with pitch-chain gearing; as in the former case, the motor is placed centrally underneath the floor, with its shaft parallel to the car axle, but only one of the pair of axles is connected by means of the chain to the toothed wheel of the armature. There is some noise and vibration with this arrangement, more current is required, and slightly less speed is obtained with this vehicle than with the other; consequently, chain-gearing must be less efficient than steel cords, the motors and all other conditions being similar.

Another line on which the ordinary rails serve as conductors of the electric current is that of Mr. Magnus Volk, at Brighton. When opened by the Mayor of Brighton, on August 2nd, 1883, it was only a quarter of a mile long, running from the Aquarium entrance to the Chain Pier; 30,000 passengers having used it during the first five months of its existence, Mr. Volk obtained permission to extend it as far as Kemp Town, a distance of nearly a mile from the Aquarium. The rails are fastened to wooden sleepers which rest upon the shingle along the beach, and no special insulation is employed; the necessity of passing under the Chain Pier involved a gradient of 1 in 28 on the west side and 1 in 14 on the east side of the pier. Two cars connected together, and containing 60 passengers, mount these inclines without difficulty. Each car, when empty, weighs 1¼ tons, and with 30 passengers about 3¼ tons; the speed is limited to eight miles an hour. The motive power in this case is a 12 horse-power gas-engine placed at one end of the line, driving a Siemens compound-dynamo, which generates a current of about 20 ampères at 160 volts when one car is running. As a rule, only one car is used, but on bank holidays and special occasions, when the traffic is great, the second car is put upon the line. The average distance made by each car last year, I am told, was 23,475 miles, and the expenses per car mile amounted to only 2d. This is remarkably low, considering that gas is used in the prime mover, costing 3s. 3d. per 1,000 cubic feet, and this item alone amounted to 1·11d. per mile; for wages ·7 of a penny was expended; oil, waste, &c., ·07 of a penny, and the repairs to machinery came to ·12 of a penny per car mile. The number of passengers last year averaged 8·51 per car mile, and the total expenses amounted to 55 per cent. of the gross receipts. On the Brighton cars leather link belts are employed for transmitting the power of the motor to the driving axle; the armature shaft is provided with a 5 inch pulley; this gears into a 24 inch pulley, on a countershaft fixed under the car. Mr. Volk used plain leather straps at first, but found them unsatisfactory, whilst the link-belts proved quite practical, after an experience reaching over a period of nearly three years. The belts slip a little at starting, but this is not considered a disadvantage, since it eases the motor; the bearings of the countershaft are adjustable by means of a slide, so that any slack caused by stretching of belts may be readily taken up. No protection is provided for the gearing, there being no mud to contend with, but I fear that this arrangement would hardly be suitable for the ordinary street cars. Judging by the large traffic which the Brighton line enjoys, one would think that it is highly popular; it is so with the public, but a section of the Town Council is opposed to the enterprise. The line was severely damaged by storms, in September, 1883, December, 1884, and October, 1886, involving a large outlay for repairs, to the anything but "permanent way." That it is a success in every way, excepting from the storms of the Town Council, and storms from across the sea, may also be gathered from the fact that a million passengers have already been carried, without injury or mishap to one of them.

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* Paper read before the Society of Arts, Wednesday, April 20th, 1887.

Coming now to lines worked by means of overhead conductors, on the plan of Messrs. Siemens and Halske, the most carefully constructed, if not the most important, is that of Mœdling, near Vienna. This is the property of the Austrian Southern Railway; the rails wind through a lovely country district for a distance of 2·8 miles, and terminate in that beautiful spot with the ugly name—Hinterbruehl.

I am indebted to Mr. C. Jenny, engineer of the Southern Railway, and to Dr. Dolinar, electrician of the Mœdling tramway, for their extreme courtesy in conducting me over the line and stations, and for allowing me to inspect every detail concerning the working of the same. Like most of the existing electric tramways, this has a large traffic during the summer months, but a comparatively small one in winter. The number of passengers carried during the year 1886 was 342,257, of these 320,000 came between April 1st and October 31st, whilst in the five remaining months only 22,257 persons availed themselves of this mode of transit. The month of August, with 72,600 travellers, stands highest in the list, and January, with 2,557 passengers, stands lowest of all. The revenue of seven months of the milder seasons is 15 times as great as the revenue of the remaining five months, but the working expenses were not at all proportional, barely as five to one, and with all that the average cost did not amount to 3½d. per car per mile, inclusive of every item of expenditure, the sum of which came to £1,700 for the year ending December 31st, 1886. The number of car miles was 91,002, with a consumption of 545 tons of coal, at 7s. 6d. the ton. This was a very inferior "brown coal," with an evaporative power of barely one-half that obtained with anthracite. The cost of fuel, therefore, came to ·54 of a penny per mile, representing a consumption of 13·4 lbs. per car mile. With coal of the best quality, 7 lbs. per mile would suffice, but the price of this, in Vienna, is more than double that of "brown coal."

The generating station is situated at the Mœdling terminus; it contains three portable engines of 12 H.P. (nominal) each, and six Siemens compound dynamos, each capable of producing 500 volts and 30 ampères. When two loaded cars are running, *i.e.*, one electric car, to which an ordinary car is attached, the indicated power of one engine varies between 12 and 20 H.P., according to the position of the vehicles relatively to the line during the outward journey. The track is not an easy one; it consists almost entirely of curves, with radii of from 60 feet and upwards. Moreover, the terminus of Hinterbruehl lies 120 feet higher than that of Mœdling; thus the line consists of a series of gradients, so that for the outward journey a considerable amount of tractive power is necessary, whilst on the return journey the cars run almost entirely by the force of gravity, and the driver touches the switch only when starting and at the sharpest curves. During the winter months one electric car suffices, and then one engine and one dynamo are used, attended by an engine driver and a stoker. In summer, when three engines, six dynamos, and six double cars are running, three stokers are required. The maximum number of journeys, each of 2·8 miles, last summer was 180 a day, with six electric and six ordinary cars coupled in pairs, and the minimum number of journeys in winter with one car was 24 per day; the time allowed for one journey is 20 minutes. There are four stopping places along the line, and the average speed allowed is 9⅓ miles an hour. The conductors—the metal ones, not the animate being of the car—are carried on posts 18 feet high and 90 feet apart, except on sharp curves, where they stand at a distance of 45 feet from each other. These conductors are made of slotted tubes, in lengths of 15 feet each, and soldered together when placed in position. To prevent them from sagging, stout wires are stretched over brackets on the tops of the posts, and fastened to the tubes half way between the posts. The bore has to be made perfectly smooth and clean, so that neither mechanical nor electrical resistance is offered to the contact carriage sliding within. The diameters of the tube are 1 inch internally and 1⅝ inches externally. The contact carriage consists of a flexible piece of flat steel, upon which three gun-metal pistons are fastened. These pistons, which have to be renewed every two months, are made in two halves, with springs in the middle, whereby a slight pressure is produced between the surfaces in contact. The resistance of the conductors is 2 ohms, and the insulation in damp weather never falls below 6,000 ohms. Measurements gave a difference of potential of 500 volts at the dynamo, and 390 volts at the furthest end of the line when three electric cars were running, and this would correspond to a current of about 18 ampères per car. All the electric cars on this tramway are fitted with spur-gearing; but I will reserve any remarks on this mode of transmission until I am describing another line worked on the same principle. The Mœdling-Hinterbruehl Tramway has been working successfully since 1884, at an average cost of 3·42d. per car mile, inclusive of every item of expense.

The second line, almost identical with the last one, as far as electrical details are concerned, is that of Frankfort-on-Main, in Germany. It leads from the "Roemerbruecke," in Frankfort, through the villages of Sachsenhausen, Oberrad, and through the town of Offenbach; its total length is 4·1 miles; it has a double track laid with ordinary tram-rails, thus differing in this respect from the Mœdling line, which has a single track with three passing places, and ordinary railway rails of a light construction. Single cars, as well as trains composed of one electric and one ordinary car, run between Frankfort and Offenbach every 20 minutes, from six in the morning until eleven o'clock at night. The entire rolling stock consists of 14 vehicles, 10 of which are fitted with electric-motors. All are constructed to carry 24 passengers; but the weight of the electric cars is four tons, empty, and that of the others about two-and-a-half tons. The engine-house is situated at Oberrad, nearly half-way between the termini. It contains two horizontal steam-engines of 120 horse-power each, and four vertical Siemens dynamos, each capable of generating a current of 70 ampères and 300 volts. Ordinarily on week days, four pairs of cars are running, when one engine, working at half-power, is used for driving two dynamos. With eight electric cars and four ordinary cars on the road, the engines indicated 164 horse-power. The average speed allowed on this line is 7½ miles an hour, and one journey occupies 40 minutes, inclusive of stoppages at eight stations.

The Frankfort Offenbach Tramway has been in operation since April, 1884; last year, 990,238 passengers were conveyed, and 292,269 car miles were run, at a cost of 3·83 pence per mile, including the following items:—

Wages and salaries of directors, clerks, &c. ...	2·23d.
Fuel (7·54 lbs. of coal per mile)	·65d.
Oil, waste, &c....	·13d.
Repairs of machinery, cars, and permanent way	·82d.

If we could deduct the directors' fees, repairs to roadway, and such items, which do not really belong to the costs of motive power and maintenance of the same, then the expenses per car mile might come to less than 3·5d.

With reference to the overhead conductor, I need only mention that the slotted tube is used in the same manner as at Mœdling, with the exception that its resistance in the present case is only 1·6 ohms, and the contact carriage is somewhat differently constructed. Instead of three gun-metal pistons made in halves, there are two solid iron pistons without expansion springs. These parts have to be renewed every three or four weeks, at the cost of 1s. for each carriage.

There are several gradients, the stiffest of which is 1 in 32 for a distance of 100 yards; another of 1 in 45, 150 yards long, with a curve of 110 feet radius upon it; and a third incline of 1 in 80, 300 yards in length. To those who study the subject of mechanical traction the following data relating to the tramway under discussion may be interesting. The energy expended was measured on the car as well as on the generating dynamo, simultaneously, when the total weight, propelled at the normal speed, was 8·35 tons, comprising one electric-car hauling an ordinary car and passengers:—

	Electrical Measurements.	
	H.P. on Car.	H.P. at Dynamo.
Running on a level road	3·87	6·47
Running up gradient 1 : 45 without curve ...	8·00	13·5
Running up gradient 1 : 45 with curve ...	9·70	16·7
Starting up gradient 1 : 150	10·2	26·4

I have already stated that spur gearing is used on the Mœdling cars as well as on those of Frankfort; concerning the working of the latter I will now submit a few particulars. The train of wheels on one of these cars consists of a pinion on the motor shaft having 17 teeth which gears into a spur-wheel of 56 teeth keyed upon a countershaft. On this countershaft is the second pinion of 26 teeth, and this drives the spur-wheel of 52 teeth fixed to the car axle. We get thus a ratio of 1 to 6·6, nearly, between the motor and the car wheels; the whole set of wheels weighs 4 cwt.; the electric motor, also, is very heavy, so that the driving apparatus of one car comes to about 26¼ cwt. It must, however, be noted that the motor runs at the comparatively low speed of 500 revolutions. A considerable amount of noise is produced by this gearing, so that the sensation felt inside the electric car is anything but agreeable. As regards the economy of spur gearing for tramcars of this description, the experience gained is not at all favourable; the pinion of the motor, for instance, which is made of hard gun-metal, wears out in a month. One of the cars is now being fitted with wheels having double helical teeth, and it is expected that these will work more smoothly, and be more durable. I am indebted to Mr. Prins, the manager, and to Messrs. Dill and Strauss, of Frankfort, for their kindness in conducting me over the line and premises, and for affording me every facility in studying the whole arrangements. Overhead conductors of a different form to those just described were constructed by Messrs. Siemens and Halske for the electric railways in the mines of Zankerode, in Saxony, and the Hohenzollern colliery, in Upper Silesia. The Zankerode line has been in operation since the autumn of 1882, and the Hohenzollern was started in August, 1883; another is now being constructed for the salt mines of Stassfurt. In all these, the conductors are made of bars in the shape of an inverted T fixed along the roofs of the mines. Sliding contact pieces grip the edges of the lower flanges of these bars, and insulated wires lead from the slides to the electrical switch on a small electric locomotive which hauls a number of trucks. An interesting description of the Zankerode line is given in Mr. F. I. Rowan's paper, recently read before the Mining Institute of Scotland. Mr. Rowan states that the cost of haulage, including 15 per cent. for depreciation of plant, came to only ·77 of a penny per ton, when 660 waggons were drawn per day of 16 hours.

Concerning the Hohenzollern line, Mr. Zacharias, of Berlin, has kindly placed his notes, which contain many details of its construction and working, at my disposal, but unfortunately our time is limited, and I can therefore give very few particulars at present. Two sets of rails are laid underground, for a length of 820 yards, and there are several curves of from 15 to 30 feet radius; about 40 trains run daily, with one locomotive and 15 waggons; each waggon carries nearly half a ton of material, and the cost of haulage is said to be about ½d. per ton.

The steam engine and dynamo are placed near the top of the shaft, 250 yards above the working level; when running at 277 revolutions per minute, the generator gives 350 volts and 37 ampères. Each waggon weighs when empty 1,210 lbs., and when loaded, a little over a ton; the electric locomotive weighs 2·1 tons, and the whole train of 15 waggons 17·8 tons, running at an average speed of seven miles an hour. For transmitting the motion of the motor to the driving wheels, two pairs of bevel wheels, one pinion, and two spur wheels are employed.

Among the lines on which the "third rail" system of conductors is used, the electric tramway of Portrush and that of Bessbrook, both in Ireland, must be considered the most important. The Portrush line, which was described in this room four years ago, is the longest electric tramway in the world; its rails traverse the country for a distance of six miles, between the terminus of the Belfast and Northern Counties Railway and Bushmills. Since the reading of Dr. E. Hopkinson's paper, important additions have been made by the installation of two 50 horse-power turbines, driven by a 26 feet waterfall on the river Bush, which is 1,600 yards away from the nearest point of the tramway. The electric resistance of the line is 1·9 ohms; the generating dynamo gives a maximum current of 100 ampères, with 250 volts E.M.F. Since water-power has been applied to produce the electric energy, the working expenses have not amounted to threepence per car mile. The cars are fitted with pitch chain-gearing. Mr. Traill, the managing engineer, informed me that he is satisfied with the working of this gear. An extension of this line is in contemplation. The Bessbrook-Newry Tramway is three miles in length, single rail of 3 feet gauge, with gradients averaging 1 in 85, the maximum being 1 : 50. In this case also, water-power is available, there being a constant supply of 3,000,000 gallons a day, with a fall of 28 feet, and part of this is utilised in a turbine which develops 62 H.P., and actuates two dynamos of the Edison-Hopkinson type, each capable of transforming the mechanical energy of 30 H.P. into electrical energy equivalent to 25 H.P., with an E.M.F. of 250 volts. Two electric cars, each capable of carrying 38 passengers, and weighing, when fully loaded, eight tons, run on this line; besides these, there are six goods waggons, with a capacity for two tons of freight per waggon. A train consists of one passenger car and several waggons, generally three of the latter. The maximum speed attainable is 15 miles an hour, but, to conform to established rules, only 8 to 10 miles an hour are actually made. The line was passed on behalf of the Board of Trade in September, 1885, and from that time to the commencement of the present year, 30,000 train miles were run, 150,000 passengers carried, and 15,000 tons of goods were hauled. The cost of propelling a train containing the full complement of passengers and six loaded waggons is said to be fourpence per mile, including wages, repairs, and rental of water-power. Chain-gearing is employed for the purpose of transmitting the power of the motor to the car-axles. These particulars were kindly given to me by Dr. E. Hopkinson.

Mr. Holroyd Smith has devised an underground conductor contained in a channel, which is provided with a slot for the free passage of the electrical contact slide. The most important application of this system on a large scale is that at Blackpool, where it is worked on a line nearly two miles in length. Descriptions of this tramway have appeared in most of the technical journals, and Mr. Smith having read several papers before scientific societies, I need not dwell upon the details of construction, but will confine myself to a few general remarks. The roadway runs along the coast; ten cars of various sizes comprise the rolling stock, the largest having a seating capacity for 56 passengers, and the smallest carrying 30 persons. At the generating stations there are two steam engines, each of 25 horse-power nominal, driving four shunt-wound Elwell-Parker dynamos, which give a maximum current of 180 ampères, with 300 volts. The E.M.F. ordinarily employed is 220 volts, which is reduced to 168 volts at one end, and 185 at the other end of the line, the generating station being situated near the middle of the tramway. From all accounts this line has proved quite successful. It was opened in September, 1884. I have not been able to obtain particulars as to the number of car miles run and passengers carried, consequently I cannot establish the relative cost, but Mr. Smith informed me that the expenses do not reach 4d. per car mile. Whilst on the Mœdling and the Frankfort tramways the resistances of the conductors are 2 ohms and 1·6 ohms respectively, the calculated resistance of the underground copper tubes at Blackpool is only ·041 of an ohm. We do not know the actual resistance of these conductors, but I should think it must very much exceed that found by calculation, considering the great fall of potential at different points of the line. In one of the papers read by Mr. Holroyd Smith, we find some extraordinary statements with regard to insulation, and consequently leakage, in his system of underground conductors:—

"Measurements were taken of the insulation of the line during construction, and 150 yards' length was found to give 4,490 ohms. The average working loss, through leakage, may be taken at 25 ampères, which, at an electromotive force of 200 volts, is equal to 7·2 H.P."

Profs. Ayrton and Perry have devised a system of conductors which is said to overcome the objections against losses arising through bad insulation. Instead of supplying electricity to one very long, perhaps imperfectly insulated rail, they lay by the side of the railway a well insulated cable which conveys the main current. A third rail, which is rubbed by the moving train, is divided into a number of sections, each fairly well insulated from its neighbour and the ground; but at any moment, only that section which is in the immediate proximity of the train is connected with the main cable, the connections being made automatically by the moving train. The loss of power by leakage is very much lessened through this arrangement, since any possible electrical contact between rails and earth is confined to that particular section upon which the train moves at the time, and connection from the surface rail to the insulated cable is made automatically by the pressure of the vehicles upon springs underneath the conducting sectional rails. Such an arrangement could scarcely be applied to ordinary street tramways, for if the sectional rails were laid flush with the roadway, then any other vehicle would, by its weight upon the rails, cause connection with the main cable.

In order to prevent the possibility of any extraneous force, other than that provided by the electric car, from making contact between surface rail and underground conductor, Messrs. Pollak and Binswanger have devised an ingenious plan. Underneath each electric car is a powerful magnet, and underneath each rail section within a thoroughly insulated trough, is an armature of iron, which, when attracted by the influence of the passing magnet, makes contact between the cable and the surface rail, and through the latter with the switch of the car motor. No external force but that of a strong magnet, therefore, can draw electrical energy from the insulated underground conductor, and since the surface rail sections are each very much shorter than a car or train, no other vehicle following or preceding in the same track will be influenced by the current. Neither the Ayrton and Perry system nor that of Pollak has been tried on any tramway, therefore no opinion as to efficiency can be formed at present, but these systems seem worthy of an extended trial.

The idea of employing secondary batteries, the stored energy of which sets the motor in motion, and with it the car, suggested itself to the earliest inventors; indeed, the principle of applying batteries to the propulsion of a vehicle containing them was actually demonstrated in the year 1839, by a Scotchman named Robert Davidson; he used primary batteries, which proved a very expensive mode of generating electric currents; the method of storing energy in accumulators was unknown at that time. To-day, we are able to convert the energy of a waterfall or of coals into electricity by means of dynamo machines having an efficiency of 90 per cent., and more. The current thus produced can be made to decompose the acidulated water in the secondary cells which contain electrodes, or plates, capable of absorbing the oxygen and hydrogen resulting from the decomposition of water; and finally, the gases thus stored re-combine whenever we desire it, and manifest themselves in the form of electric energy capable of doing mechanical work through an electric motor. As transformations of energy always involve some loss, so there is a loss in this electro-chemical conversion, amounting to from 25 to 30 per cent. In order to establish a comparison between a system having conductors and one having accumulators carried in the cars, we have, in the first place, to ascertain the efficiency of the conductors in the one case and that of the secondary battery in the other. The efficiency of a conductor depends upon its resistance and the current transmitted. Let us take for an example a tramway similar to the one at Mœdling, with a conductor of 2 ohms resistance, 20 ampères of current for each car, and 500 volts E.M.F. at the terminals of the charging dynamo. Supposing that only one car was running on this line, then the waste of energy would be practically *nil* at the commencement of its journey from the generating station, but it would be $20^2 \times 2$ when it approaches the furthest end of the line; the average resistance, or that due to half the length of the conductor is 1 ohm; therefore the average loss is only $20^2 \times 1 = 400$ watts, against $500 \times 20 =$ 10,000 watts generated by the dynamo; consequently the efficiency of the conductor comes to 96 per cent., since we lose only 4 per cent. With six cars on the line equally distributed, and using, together, 120 ampères, the loss will be 14,400 watts out of 60,000 produced at the station, and then the efficiency is only 73⅓ per cent., and so on, by increasing the number of cars, and with it the current, the efficiency gets less and less. With the accumulator system, on the other hand, we have a constant loss, no matter how long the line, provided that the quantity of energy stored is sufficient for the time, and it matters not how many cars run at any time on the same tramway. If the cars at Mœdling were fitted with accumulators, then the weight to be propelled would have to be increased by at least 20 per cent., and this would entail a corresponding augmentation of power, in order to keep up the same speed, therefore a greater consumption of fuel would be the result. But we have seen that the item of fuel really plays a minor part in the total expenditure, in fact, it is only about 16 per cent. of the whole, hence we need not look upon the question of the loss of energy with too critical an eye. According to the report issued by the jury of the Antwerp Exhibition, a *resumé* of which has been presented to this society by Captain Douglas Galton, the consumption of fuel with the accumulator car came to 6·16 lbs. per mile, which, at 16s. the ton, costs little more than ½d. This car, however, carried only 34 passengers, and the line was practically level. On the other hand, the steam engine employed was an old portable engine, which did other work besides charging the accumulators of the tramcar. For practical tests made with cars of my own design, here and on the Continent, I have ascertained that the consumption of fuel need not exceed 8 lbs. per car mile on ordinary tram lines in towns, provided that the weight of the accumulator carried on the car does not exceed 25 cwt.

Viewed from the standpoint of convenience, the propulsion of tramcars through the medium of secondary batteries must be conceded to be second to none. The battery occupies no valuable space when stowed under the seats, while the motor, with its attachments, can be placed underneath the car. There is no interference with the permanent way, and for city traffic such a service ought to be found eminently applicable.

The last system on our list is that of the separate locomotive, carrying accumulators within, and hauling an ordinary car behind it. I have placed this at the bottom of the list, because it is the latest, but, from all appearances, it will be the first electric system to be adopted on a tramway in London. The early adoption of electric locomotives is partly due to the progressive spirit, the energy, and perseverance of the North Metropolitan Tramway Company, but mainly, perhaps, to the vigorous enterprise of the Electric Locomotive and Power Company, which exploits the patents of Mr. Elieson, its energetic manager. I have recently had the privilege of witnessing trial trips with six of these locomotive engines Mr. Elieson has prepared a diagram, from which the details of construction can be seen.* The mechanical connection of the motor with the axles is very ingenious. Each of these locomotives weighs nearly seven tons, and this is the only disadvantage one can think of when examining the system. These engines have been ready for some time, and they would have been earning money long before now, but for red tape and Acts of Parliament. Before we can run electric cars in this country we must have an Act of Parliament. To obtain one takes a year or more. It causes an immense amount of trouble and expense to get an Act of Parliament, and the worst of it is that each company has to apply separately for it; it is this awkward circumstance which retards the progress of electric locomotion on tramways in this country. On the Continent of Europe, and in the United States of America, there are dozens of electric tramways at work to the satisfaction of everybody; here in England, the home of the dynamo machine, the country where the electric motor has found its highest development, we have few opportunities for demonstrating their advantageous applications. With regard to America, there are electric tramways at work in New York, Philadelphia, Baltimore, Saratoga, California, New Orleans, Toronto, Detroit, Windsor, Chicago, Cleveland, Montgomery, Denver, and in other parts. The American capitalist encourages electrical enterprise because it is worthy of every encouragment when untrammelled by unnecessary legislation.

I have made out a strong case in favour of electric traction. Any electrician sitting at home in his arm chair can reckon out upon paper what electric locomotion ought to cost, but I have made it my business to travel from place to place and examine into the details of the actual working electric tramways. Practical men want figures based on facts, not estimates. Through the courtesy of the engineers of the oldest lines I have obtained data which renders the question of cost beyond doubt, and we have seen that the entire working expenses of those lines do not exceed —or need not exceed—3½d. per car mile. There is no reason why these expenses should exceed 3d. per mile, when the most efficient machines of the present day are applied.

Electric locomotion includes numerous other applications of the motor besides tramways, but I must stop short at this stage of the subject, having already trespassed beyond the usual limit of time.

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* See ELECTRICAL REVIEW for December 5th, 1885.

NOTES.

Electric Lighting at Cathcart.—On Saturday last the offices and platforms of the Caledonian Railway station, together with a block of shops in Queen's Crescent, Cathcart, were brilliantly lighted with incandescent lamps, fed by Kennedy's transformers. The current was transmitted from the dynamo to the transformers by means of small sized wires carried openly upon poles. Much satisfaction was expressed at the marked steadiness of the lights, and a very favourable impression was created. The wires are to be extended in various directions, and, when completed, will thoroughly illustrate Mr. Kennedy's invention. Meanwhile, we content ourselves with recording the fact of his success in this direction, reserving for a future issue the details of so interesting an installation.

Electric Lighting in Switzerland.—The electric light installation at the railway station at Chiasso (Gothard railway), *Industries* states, was inaugurated on March 31st, with complete success. The Municipal Council in Geneva has granted permission to a local electric lighting company to supply electricity for lighting purposes to private consumers in that town during a period of nine years. Since hitherto the Geneva Gas Company has had the monopoly of the lighting, it is likely that this will lead to litigation.

Was the Electric Light Really to Blame?—The electric light has been blamed, says the *Gas World*, for a serious delay in repairing the Huy tunnel on the North Belgian railway. The tunnel broke down, and then the electric light apparatus, fitted up in order to enable the workmen to proceed, failed to give light. If the fall of the tunnel severed the conductors, or in any other way injured the electric lighting plant, it is difficult to see how the electric light is to be blamed. Gas, oil, or even candles would have been equally affected by a sudden accident of the kind which occurred in the Huy tunnel.

Electric Lighting in Berlin.—The Town Electric Works of Berlin have resolved to set up a new central station, and, for that purpose, to raise their capital of £150,000 to £325,000. The new capital is to be raised by a syndicate, in which the German Edison Company takes part, and proposes to increase its own capital, with that view, by £75,000.

Something Wrong with the Electric Light.—The *Journal des Usines à Gas* Brussels correspondent says:—"The lighting of the Hotel de Ville seems to be in a very bad way, if one may judge by the numerous consultations of scientific celebrities which follow one another without interruption in the cellars of the Maison du Roi, where the patient is installed. Everyone is in the greatest perplexity: some blame the dynamos: M. Gerard replies that the fault is in the Benz motors which were in some sense forced on him; others think the plan of distribution not a good one; while some even blame the gas pipes. Agreement as to a solution of the problem seems impossible; and meantime the staff has reverted to the old gas, which serves them more faithfully, and the electric light may now shine or go out as it pleases without producing any disturbance."

No Ventilation with the Electric Light.—The inhabitants of Tours have, according to the *Journal des Usines à Gaz*, been suffering under a new discomfort. The electric light produces no ventilation: tobacco smoke accumulates in the cafés, and the visitors have to go out in order to obtain their necessary supply of oxygen.

Central Electric Light Stations on the Continent.—An electric light station has been established in the Passage des Panoramas, Paris, states *Industries*, the original contractor being M. Henry Liepmann, who has now sold the undertaking as a going concern to the Société Electrique. The engines are placed in the cellar of the establishment known as the Bains de la Presse, and instead of paying a rental, the company furnishes light and hot water to the proprietors of the bath. At present, 850 Woodhouse and Rawson lamps of 10 C.P. are fixed in various restaurants, cafés, shops, and in the Theâtre des Variétés; 400 lamps more have been contracted for in the neighbourhood, making a total of 1,250 lamps. To supply current for this number of lamps will require some additions to the plant, and these will be made during the coming summer. The current is supplied by compound wound Gramme dynamos. The example of Chateaulin is being followed by Bruyeres, a small town of 3,000 inhabitants in the Department des Vosges, about 15 miles from Epinal, where the River Arentelle furnishes abundant water power, which will be utilised for driving dynamo machines. The installation is being put up by the Maison Breguet, of Paris, and will at first only comprise 100 glow lamps; but it is to be extended if the demand for light should increase.

Electric Lighting at Homerton Infirmary.—On Saturday last we had the privilege of inspecting the electric lighting of the male wards in the new portion of Homerton Infirmary, under the able guidance of Dr. Gordon. Some time ago the Board of Guardians of the Hackney Union resolved to try glow lamps, and the result now obtained is so good that it appears certain the light will be generally adopted throughout the establishment to the number of some 700 lamps, and, as a matter of fact, it has been decided to extend operations to the chapel and dining-rooms almost immediately. Dr. Miller has long advocated the use of electricity, and medical men who have visited the wards are of opinion that it is exceedingly well adapted in all respects to the purpose applied. The wards in the building through which we were escorted are six in number, with a total of 180 beds, and a space of 850 cubic feet is allowed for each patient. 120 lamps of 16 candle-power each are employed in conjunction with 100 15-plate cells of the Elieson type, connected up in two groups of 50. A "Phœnix" dynamo, driven by the engine which is used for pumping, is employed for charging, and there is ample boiler power for a much larger engine or several smaller ones. Charging goes on for about four hours every third day, and this suffices to enable the accumulators to supply all demands. We understand that this is the first institution of the kind in London to adopt electric lighting, and the guardians are to be congratulated upon their spirited policy, which we trust may be the means of inducing other similar establishments to go and do likewise. The installation, which appears very perfect, has been carried out by the Electric Locomotive and Power Company, under the direction of Mr. C. P. Elieson, and it is now in charge of Mr. W. R. Jeffray, the infirmary steward.

Train Lighting by Electricity.—The regular Boston "special" on the Boston and Albany Railroad is now lit by electricity and heated by steam. The lighting is from accumulators, 60 cells being placed in each car, these having been charged before leaving the depôt. These 60 cells are found sufficient to keep the illumination in force during the journey from Boston to New York and back, so that but one electrical station is necessary. In every car there are 20 incandescence lamps, each of 16 C.P.

Paris-Brussels Telephony.—The telephone line from Paris to Brussels, *Industries* states, has been connected at Brussels with that joining the latter town and Amsterdam, so that now it is possible to speak direct from Paris to Amsterdam.

Proposed Extension of the French Atlantic Cable.—According to a dispatch from Halifax, N.S., dated April 1st, Superintendent Fisher, of the French cable company, has stated that it is the intention of his corporation to immediately begin the construction of land lines connecting its cable at Sydney with Montreal, and there securing ultimate connections with the Baltimore and Ohio and the Canadian Pacific systems, and obtaining direct communication with New York independently of its cable from St. Pierre to Cape Cod. He says that the French company will give the best possible service at the lowest possible rate.

The Commercial Cables.—A break recently occurred in the Mackay-Bennett cables, but was so promptly repaired that the company's customers could not refrain from expressing their appreciation of the efforts made to serve them. One well-known banking house wrote to Mr. Ward, the Commercial Company's manager, as follows:—"We congratulate you on having the cables repaired so promptly, and those persons in daily communication with London can be congratulated also. During the days you were not working our cables by the Western Union were from two to four hours without reply. This morning we cabled London by your line, and in regular course received a reply in 22 minutes." The breaks in the cables were in the Bay of Dover, near Canso, Nova Scotia. The working of the southern cable was first interrupted at 24 minutes past 11 a.m. on Tuesday, March 29th, and the northern cable ceased its functions on the following morning. The weather was very bad, and it was not until Friday, April 1st, that the *employés* of the company succeeded in getting at the breaks. Late on Saturday night the repairs were completely effected. As an illustration of the spirit encouraged by the considerate treatment of *employés* the following memorial, presented by the staff at the various offices to the superintendents, deserves to be recorded:—"We, the undersigned, members of the staff, desire you to express to the president our profound regret at the misfortune which has fallen upon the company. He has been very generous to us in times of prosperity, and we think the least we can do is to offer to place ourselves on half pay while the interruption lasts." This generous proposition was declined, and the staff of the company was continued on the pay rolls at full pay during the whole period of interruption to business.

The Simplex Arc Lamp.—The writer of New York Notes in the *Electrical World* states that he recently witnessed a test, at the offices of the Electrical Construction and Supply Company, of the new Simplex arc lamp, which behaved very satisfactorily. It was placed in multiple arc on the Edison circuit, and, being supplied with a 10 ampère current at 52 volts, it furnished a light of 2,000 C.P. The lamp will, it is said, work on all the standard systems. One feature is that it has but four plain movable parts. No variations could be observed in the incandescent lights on the same circuit.

Transformers.—The Gaulard and Gibbs transformers, *Industries* states, are going to be worked in Belgium by a powerful syndicate of financiers. On the other hand, the Zipernowski-Deri-Blathy system is also meeting with considerable favour.

Royal Society.—Amongst the papers announced for reading last night was a paper by Prof. H. Lamb, F.R.S., on "The Principal Electric Time-constant of a Circular Disc."

The Electro-Harmonic Society.—The second smoking concert of this society will take place on Friday evening next. The programme, which is of a nature to suit all tastes, may be found on p. 2 of supplement, and lovers of both instrumental and vocal music will find enough and to spare of good things.

The Electro-Dynamic Treatment of Disease.—It is much to be deplored that members of the medical profession have not more generally made themselves acquainted with the science of electricity. That the application of an electric current to the human system may in certain cases be attended with highly beneficial results, both in the alleviation of suffering and the removal of disease, is placed beyond dispute by the experiments and observations of such eminent medical men as Dr. Herbert Tibbits, Dr. A. de Watteville, Dr. W. H. Stone and others; but only very partial attempts have as yet been made to discover the extent to which electricity may be employed for curative purposes, and the field has been left far too much to the charlatan, who has not scrupled to claim all-healing powers for the force regarding which he is just sufficiently informed to make him a dangerous man to deal with. It is imperative for the proper use of the agency of electricity that it shall be employed only by men of proved ability in medicine as well as in electrical knowledge. To the physiologist electricity is undoubtedly of the utmost value; but in the hands of ignorant quacks it may have results the reverse of those desired. It is necessary therefore that persons seeking relief should assure themselves of the *bonâ fides* of those into whose hands they place themseves. Mr. W. Lynd, F.R.M.S., M.S.T.E., who lately conducted the West London School of Telegraphy and Electrical Engineering, has now turned his attention to the treatment of disease by electrical means, and has opened an establishment in Bloomsbury Street, under the name of the Electro-Dynamic Medical Institute, where he announces his readiness to receive and treat patients during stated hours. Lectures to the medical profession on electro-physiology and electro-therapeutics, and to the general public on electro-dynamic treatment, are shortly to be given at the institute. If Mr. Lynd can succeed in inspiring medical men with confidence in his methods and his abilities, he will no doubt achieve that success which his plucky effort to demonstrate the good effects of the scientific and systematic treatment of disease by electricity undoubtedly deserves.

King's College London.—Professor W. Grylls Adams, F.R.S., will deliver a course of lectures on Electro-Magnetism, Magneto-Electricity, the Testing of Motors and Dynamos, Electric Lighting, Transmission of Power, during the present term. A course of practical work in Electrical Testing and Measurement with especial reference to electrical engineering will also be carried on under his direction in the Wheatstone Laboratory. The lectures will be given once a week—on Mondays at 2 p.m., and the Laboratory will be open daily from 1 to 4, except on Saturdays.

Removals.—The Union Electrical Power and Light Company's offices have been removed from 127, Cannon Street, to Palace Chambers, Westminster.

Messrs. Martin and Co., late of 54, Percival Street, E.C., have removed to Mildmay Park Works, Newington Green Road, Islington, N.

The Chandler Engine.—Mr. Bumsted, of Hednesford, the maker of these engines, has lately supplied three of them for three steamers plying between London and Glasgow. They are of the single cylinder type, 8 inch bore and 6 inch stroke, driving the dynamos direct at 400 revolutions per minute. Messrs. Wm. Harvie and Co., of Glasgow, fitted the electrical plants; the dynamos are "Phœnix," and give 110 lights.

Royal Institution.—Dr. John Hopkinson, F.R.S., delivered the first of four lectures on "Electricity," at this Institution, on Tuesday, the 19th inst.

The Society of Telegraph-Engineers and Electricians.—In compliance with the request of many of the students of the society, the council have arranged that a series of students' meetings shall be held in the library of the society for the following purposes:—1. Reading and discussing papers written by students. 2. Discussing papers read at the general meetings of the society. 3. Discussing questions of interest in connection with electrical science. These meetings will be held during the present year on the following Thursday evenings, unless an extraordinary general meeting of the society should be convened for any of them, in which case the students' meeting will not be held:—May 5th, May 19th, June 2nd, November 17th, December 1st, December 15th. The meetings will commence at 8 p.m. and will close at 9.30 p.m. Each meeting will be presided over by a member of the council, or some other member of the society, but, with that exception, students only will be allowed to attend. A notice, stating what paper will be read or subject discussed at each meeting, will be placed on the notice board in the hall of the Institution of Civil Engineers on the previous Thursday evening. Papers by students must be sent in to the secretary for approval of the council before being read. Should any paper written by a student, and read at one of the students' meetings, possess in the opinion of the council sufficient merit, it will be published in the society's Journal, and will be taken into consideration in connection with the award of the society's annual premiums.

The next meeting of the society will be held at 25, Great George Street, S.W., on Thursday, April 28th, when the following papers will be read:—1. "Measuring the Coefficients of Self and of Mutual Induction"; 2. "Driving a Dynamo with a very short belt," by Profs. W. E. Ayrton and John Perry, F.R.S., members.

The Proposed Electric Railway at Littlehampton.—As might have been anticipated from our report of the Board of Trade enquiry, permission has been refused for the establishment of an electric railway to run between the railway station and the sea front at Littlehampton, and the scheme therefore falls through for the present. In recommending the Board of Trade to withhold its consent, General Hutchinson regretted that he could not give effect to the opinion of the majority of the Local Board and so many of the tradespeople, who were strongly in favour of the scheme. But for the difference of opinion, the narrowness of some of the streets, and the objection of the Duke of Norfolk, it is understood that the inspector would have recommended the Board to permit the establishment of a horse tramway, the lines to be so laid that when more experience had been gained with regard to their working, electric trams might be substituted. The matter will probably not be allowed to drop, in spite of this official "damper," and if circumstances prove favourable in the meantime, an Order in Council may be applied for next session, a different route being selected in order to dispose of the objection as to the narrowness of the thoroughfares through which it was originally proposed to pass.

The Brighton Electric Railway.—Considerable controversy is still indulged in with reference to the proposed suppression of Mr. Volk's lucrative little enterprise at Brighton, and advocates of the railway urge that so far from the line being removed every encouragement should be afforded the proprietor to extend it as far as Hove. It is hoped that the weight of the majority of the members of the Corporation "will be thrown in the scale in opposition to an act of Vandalism, initiated and fostered by an obscure knot of interested agitators."

Electricity in the House.—The *Electrical World* understands that Mr. E. H. Johnson, president of the Edison Company, will have at his new country house at Greenwich, Conn.. one of the most extensive—probably by far the most complete—outfits of electrical apparatus, for domestic use, to be found.

Electrical Traction at Brussels.—The *Bulletin International de L'Electricité* states that five cars have been actually fitted up on M. Julien's system, and the inauguration of the service is announced for the end of this month. This date may be a little too soon, but we may reckon on the cars being in operation by May 15, notwithstanding the difficulties which M. Julien has to deal with at present, one being that the representative of Messrs. Siemens at Brussels threatens the tramway company with an action for infringement in connection with the armature of the machine employed by M. Julien. This matter, which is to be submitted to examination by experts, will cause some excitement in Brussels.

Obituary.—We regret to announce the death of M. A. Gaiffe, electrical engineer, who died at the age of 55 years. M. Gaiffe was known principally through the improvements which he introduced in the applications of electricity to medicine, and the numerous electro-medical apparatus which he invented. He was, moreover, instrumental in introducing the new industry of nickel plating into France.

Societe Internationale des Electriciens.—At the last meeting of the above society, M. Mascart was nominated President for the year 1887. The post of Secretary-General was created and conferred on M. Seligmann Lui, telegraph engineer.

"Science and the Jubilee."—This is the title of a lecture descriptive of the great discoveries and inventions of Her Majesty's reign, which Mr. Eric S. Bruce, of electrical war balloon fame, is to deliver next Thursday at the Prince's Hall, Piccadilly.

The Royal Society, Edinburgh.—At the meeting on Monday, the 18th, the president, Sir William Thomson, read a paper "On Ship Waves," and one on "The Instability of Fluid Motion." Principal Jamieson communicated a paper by Mr. D. S. Sinclair, of Glasgow, on "An Experimental Research in Magnetism." Mr. Sinclair finds an empirical formula for the magnetic moment of short iron bars and within the range of the experiments is able to predict for any bar when saturation will commence, that is the strength of field at which the moment ceases to be proportional to the magnetising force.

The Colonial Conference and Telegraphic Communication.—The Colonial Conference on Wednesday considered the subject of telegraphic communication, with special reference to the question of uniting Canada and Australia by cable, but, as the sittings of the Conference are private, we are unable to give our readers any information as to what took place. The official announcement states that it was agreed that further papers should be printed and distributed, the discussion being adjourned until Wednesday next.

Electric Lighting of Turin.—We are informed by Mr. J. W. Lieb, of Milan, that after a number of unsuccessful attempts to light a portion of the city of Turin with the Gaulard and Gibbs system, the original project has been abandoned. The Zipernowski-Déri system is now being used for the incandescent lighting, and the Thomson-Houston system for the arc lighting.

Demagnetising Watches.—"N. A. R." writes:—"In reply to 'P.E.R.', I might suggest that his watch should be protected from the effects of external magnetism on the same principle as the marine galvanometer, *i.e.*, he might have an iron case made to enclose the entire watch, with as small a space as is convenient left open for the face. As 'P. E. R.' is not pressed for room, the case should not be made too thin, and it should be of as soft iron as possible. I think that by these means his watch will be protected, at any rate in a great measure, if not entirely, from the effect of external magnetism."

"Arc" Lighting at the Manchester Jubilee Exhibition.—We are informed that the Anglo-American Brush Company had a very short trial run on Wednesday evening at the Manchester Exhibition, which went off fairly well. The dynamo employed was a 40-light machine, giving an E.M.F. of 2,000 volts and a current of 10 ampères; but on this occasion it was only lighting 35 lamps. The other lighting, we are informed, is well forward, the Manchester and District Edison Company having the lion's share of the incandescent branch, while Messrs. Galloway and Sons are supplying the light to the illuminated fountains in the grounds. The whole is expected to be running by Monday next.

Telephone Communication between Glasgow and Renfrew.—The extension of the telephone to Renfrew has been completed. An exchange will soon be opened in that town.

Specifications Published.—No. 3,945, Improvements in electrical switches, Robert Major Baily and Alfred Grundy, 20th March, 1886; No. 3,946, Improvements in the method of and apparatus for transforming the conditions of electric currents, Louis Bollmann, Ernest Biedermann, and Demêtre Monnier, 20th March, 1886; No. 4,308, Improvements in dental engines operated by electricity, Amos Kirby, 27th March, 1886; No. 4,663, Improvements in electric generators, Franz Filipp Stogermayer and Victor Glassner, 2nd April, 1886; No. 5,588, Improvements in dynamo-electric machines, William Morris Mordey, 22nd April, 1886; No. 5,664, Improvements in and connected with electric motors and the transmission of power therefrom, Michael Holroyd Smith, 24th April, 1886; No. 6,220, Improvements in electrical switches, Michael Holroyd Smith, 7th May, 1886; No. 111, Improvements in an electrolyte and depolarising solution for voltaic batteries, William Crocker Quinby, 4th January, 1887.

Philosophical Society of Glasgow.—By the invitation of Sir Wm. Thomson an extra meeting of this society was held on Wednesday, when the following communications were made and experimentally illustrated:—"On a Double Chain of Electrical Measuring Instruments to Measure Currents from the Millionth of a Milliampère to a Thousand Ampères, and to Measure Potentials up to Forty Thousand Volts," by Sir Wm. Thomson, F.R.S.; and "On Heat Radiation," by Mr. James T. Bottomley, M.A., F.R.S.E.

NEW COMPANIES REGISTERED.

Pertwee Gray and Company, Limited.—Capital: £1,800 in £10 shares. Objects: To carry on business as chemists and druggists, and as makers and dealers in electrical, chemical, surgical, and scientific apparatus and materials. Signatories (with one share each): *G. Gray, T. Davey, S. Fletcher, and H. Poston, all of Romford, Essex; *G. Paul, Brentwood; *A. B. Daniel, 39, Fortess Road, Kentish Town; J. H. Read, 818, Holloway Road. Directing qualification: £10 in shares or stock. The company in general meeting will determine the remuneration of the board. Registered 16th inst. by W. H. Lea, 50, Chancery Lane.

Singapore, Straits Settlement, and Siam Electrical Company, Limited.—Capital: £60,000 in £5 shares. Objects: To carry on at Singapore, Straits Settlement, Siam, and elsewhere in the far East, the business of an electrical company in all branches. Signatories (with one share each): *F. L. Rawson, W. Foote, and J. H. Ward, of 11, Queen Victoria Street; J. Shurmer, 4, Gilbert Road, S.E.; A. Stevens, 80, Fernhead Road, Paddington; W. S. Rawson, 68, Cornwall Gardens; D. Potter, 112, Chetwynd Road, N.W. Directing qualification: 20 shares or £100 stock. Mr. Harry Seymour Foster is appointed a director. The remuneration of the board will be £100 per annum in respect of each director. Registered 16th inst. by Dubois Reid and Williams, 3, Pancras Lane, E.C.

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* Signatories whose names are preceded by an asterisk are also directors.

OFFICIAL RETURNS OF ELECTRICAL COMPANIES.

Dixon & Corbett and R. S. Newall & Company, Limited (wire rope and cable manufacturers).—An agreement provides for the purchase of the goodwill, freehold and leasehold hereditaments and effects of R. S. Newall & Co. for £27,000, and stock-in-trade to be purchased at a valuation. For the goodwill, property and effects of Dixon & Corbett, the consideration is to be £47,000, with valuation price for the stock-in-trade. The former amount is payable as to £17,000 in fully-paid ordinary shares and £10,000 in cash; the latter amount is to be paid as to £45,000 in fully-paid ordinary shares and £2,000 in cash. Messrs. George Dixon and John Corbett are appointed managing directors for seven years at salaries of £500 per annum. Registered office: The Team Rope Works, The Teams, Gateshead.

Hermite British Electro-Bleaching Company, Limited.—The patents taken over by this company are as follows:—No. 5,160, dated October 30th, 1883; No. 13,929, dated October 21st, 1884; No. 3,956, dated March 20th, 1886; No. 3,957, March 20th, 1886; and provisional specification, No. 14,673, dated November 12th, 1886. The purchase consideration is 500 fully-paid A shares to Mr. Hermite and the like number to Messrs. Paterson & Cooper. The sum of £2,000 will also be paid by the company in respect of amounts expended by the vendors in the premises agreed to be sold, and in the development thereof.

Railway Electrical Contractors, Limited. — The annual return of this company, made up to the 7th inst., was filed on the 18th inst. The nominal capital is £25,000 in £5 shares, the whole of which are taken up; 3,750 shares were issued as fully paid, and 750 were issued for £750 cash. Upon 500 shares the full amount has been called, and 4,500 shares are considered as fully paid up. The calls paid amount to £2,600.

Foreign Pilsen Electric Light and Power Company, Limited.—The annual return of this company, made up to the 14th inst., was filed on the 15th inst. The nominal capital is £30,000 in £1 shares; 29,800 shares have been allotted, and the full amount has been credited as paid up thereon.

Singapore, Straits Settlement, and Siam General Electric Company, Limited.—The annual return of this company, made up to the 19th March, was filed on the 4th inst. The nominal capital is £60,000 in £5 shares. Seven shares have been taken up, and the full sum of £35 has been paid in respect thereof. The company is now in course of dissolution, and consent has been given to the registration of a new company under the title of the Singapore, Straits Settlement, and Siam Electrical Company, Limited.

Anglo-Continental Electro-Medica Vapour Baths Company, Limited.—At an extraordinary general meeting of the members of this company, held at 139, Cannon Street, on the 29th ult., it was resolved to wind up voluntarily, and Mr. Edward Schuberth, creditor and accountant, was appointed liquidator. The resolution was confirmed on the 13th inst. and duly registered 16th inst.

CITY NOTES.

Reuter's Telegram Company, Limited.

THE report of the directors states that the net profits for the year ending 31st December last, after payment of current charges, and deducting rebate on unexpired subscriptions, amount to £6,772, including £613 brought forward from the last account. An interim dividend of 2½ per cent. was paid in October last, and the directors now declare a further dividend of 5 per cent., making a total distribution, free of income-tax, of 7½ per cent. for the year. This will absorb £5,585, and after adding £1,000 to the reserve fund, there will remain a balance of £186 to be carried forward. In accordance with the articles of association, Colonel James Holland retires from the direction, but offers himself for re-election. The auditors, Messrs. Quilter, Ball & Co., also offer themselves for re-election. The dividend warrants will be payable on the 30th inst.

United River Plate Telephone Company, Limited.

THE statutory meeting of this company was held at Winchester House on Friday last, Lord Thurlow presiding. The chairman stated that the capital had been fully subscribed, and the vendor companies had been paid the sums agreed upon in the manner provided. The total sum paid was £290,000 in equal proportions; of this amount £170,000 was paid in cash, £40,000 in 7 per cent. debentures, and £80,000 in 16,000 fully-paid shares. A quotation had been granted to the shares of the company by the Stock Exchange Committee. Everything was proceeding satisfactorily at the River Plate. There had been only 150 withdrawals consequent on the raising of the rates which took place before the amalgamation, and most of these were coming back. Major H. J. S. Fitzgerald and Mr. F. Green were re-elected directors, and Messrs. Cooper Bros. & Co. were elected auditors to the company, this comprising the whole of the business.

TRAFFIC RECEIPTS.

The Western and Brazilian Telegraph Company, Limited. The receipts for the week ending April 15th were £2,921.

The Brazilian Submarine Telegraph Company, Limited. The receipts for the week ending April 15th amounted to £3,611.

CORRESPONDENCE.

The Practice of Dynamo Design.

In your criticism of my papers on the "Practice of Dynamo Design," you endeavour to illustrate by sarcastic analogy the unnecessary and cumbersome character of my work.

If the work be really superfluous, you are quite justified in being funny over it, but even then it would be as well to use a rational analogy.

The one which you institute is based on the impossible hypothesis that the load on a steam engine might be expressed in terms of the steam pressure only, without reference to the size of the cylinders, and this is sufficiently absurd and futile without going any farther with it.

What I have done is to express the linear dimensions of a dynamo in terms of the general configuration of the armature, out-put, speed and magnetic induction per unit area. These quantities constitute what is already known and what may be assumed about the machine to be constructed; the linear dimensions are what have to be found.

Most schoolboys would, therefore, understand that the proper and rational course would be to express the one unknown quantity in terms of the known quantities.

You, however, would seem to suggest that some other course should be pursued, and that instead of making the linear dimensions fit the actual requirements of the machine; other quantities, such as the winding and magnetic induction per unit area, should be made to fit the linear dimensions; thus the latter may be anything we please, and the final adjustment of the dependent quantities must be left to luck and to the application of the "homely foot-rule."

I confess that I am not good at such flying shots and should have hardly expected to have seen them advocated in a technical journal of the present day.

As a matter of fact, although the general expression which you quote is necessarily somewhat long and unwieldy, the practical form (which you carefully omit) in which it would be applied to a particular type, viz.:—

$$R = B\left(\frac{E\,C}{\mu\,n}\right)^{\frac{2}{7}}$$

is not such as to astound or mystify any dynamo maker with whom I am acquainted.

Guy C. Fricker.

[Our correspondent in his concluding paragraph candidly admits the long and unwieldy character of his formula. Under the circumstances this is all we can ask for, and it would serve no good purposes to criticise the petulant remarks leading up to the final admission. We shall most likely have to write of these papers again.—EDS. ELEC. REV.]

Determining the Coefficient of Self-Induction.

The new method for measuring the coefficient of self-induction, communicated by MM. Ledeboer and G. Maneuvrier to the *Comptes Rendus*, and described in your issue of April 15th, was devised by Prof. Perry and myself exactly a year ago, and a preliminary instrument for carrying out this method was constructed by us and used by one of our students, Mr. Sumpner, in the summer of last year for measuring a number of coefficients of self-induction. The theory and action of our apparatus has been explained by me to classes of students at the Central Institution, and the apparatus, which has been in constant use in the electrical laboratories there, forms the subject of one of our patents. Many improvements have been introduced into the apparatus during the last six months, and a description of the method in question, together with an exhibition of some of the types of the instrument which have been developed, with the aid of one of our assistants, Mr. Bourne, is announced as the subject of a paper at the next meeting of the Society of Telegraph-Engineers and Electricians on the 28th inst.

Our instrument we have called a "Jenkmeter," and we venture to suggest that one ohm second or one earth's quadrant, which is the commercial unit of self-induction, should be called "one Jenkin," since the late Prof. Fleeming Jenkin was the first to observe the phenomenon of self-induction.

That MM. Ledeboer and G. Maneuvrier, who have worked so much at the measurement of the coefficients of self-induction, should have independently arrived at our method as the best in their estimation is a source of real pleasure to me.

W. E. Ayrton.

A Method of Charging Secondary Batteries.

Allow me in answer to Mr. Giltay's letter in your REVIEW of April 15th, to mention that an account of the polarisation battery and current reverser may be found in a paper read before the Berlin Academy of Science, December 21st, 1843, so that I was only wrong in my date by one year, not 22. Sir W. Grove in his correlation of the physical forces mentions a commutator for a single cell, p. 253; the date appears to be about 1840. Being away from Oxford when I wrote the former communication, I was unable to refer to the passages now mentioned.

Frederick J. Smith.

April 16*th*, 1887.

P.S.—There is a slight typographical error in the text of the communication on p. 333; for "electrolytes" read "electrolysis."

Single Needle Duplexing.

I observe with surprise that my letter in the ELECTRICAL REVIEW of the 8th inst. on the above subject has caused considerable discomfort of mind to the Telegraph Superintendent of the Caledonian Company, as illustrated by his supreme and lengthy article in your issue of the 15th inst. I was by no means prepared for such an exuberant effusion of words with so little practical meaning or value as his letter contains. On the contrary, I had rather looked for an honourable apology from him for the act of piracy, committed, as I expected him to say, through want of knowledge of what had passed in electrical science 14 years ago. Sir, I would consider it an abuse of the privilege of your columns, as well as a frittering away of time, were I to single out and dispose of all the useless matter contained in Mr. Dunn's letter, but, with your kind indulgence, I will refer to such portions of it as are directly relative to the subject at issue, and leave the superfluous bunkum to the judgment of such of your readers as may, by chance, have taken the trouble to read it.

The main, indeed, I may say the only, subject at issue is whether the duplexing of single needles, stated to be now in operation on the Caledonian Railway, *is new, and, at the same time, the production of the telegraph superintendent of that company.*

I most emphatically say *No*, and that I am in a position to prove in the most conclusive manner possible that precisely the same system with split coils, *not differentially-wound coils*, was established by me and worked on the North British Railway 14 years ago. I am not at issue in any definite way on any other point in this controversy. In my previous letter I stated in the following plain words the causes which led to the abandonment of the system on the North British Railway, viz.:—"The ever-varying resistance of the line wire, necessitating constant adjustment of the rheostat, the inability of the receiving clerk to obtain a repetition of any doubtful words without the aid of the sending clerk, the important fact that more clerks are required for the duplex than for the ordinary single needle working, and that the expedition in the former, *all things considered*, is less rather than greater, the system was abandoned as reverse to advantageous to the railway service." To this statement I adhere, content to leave the why and wherefore to the judgment of the practical. I further stated that "if any corroboration of the wisdom of this course is wanting, it may be gathered from the coincidence that in the 14 years since elapsed neither the Postal Department nor any *railway company* had reverted to the system." It will be observed that Mr. Dunn, in his anxiety to get clear of the dilemma in which he has unwittingly placed himself, adroitly omits the words, "nor any *railway company*," then goes on to say that the Postal Department had no single needles to duplex, and, finally, employs some far-fetched remarks of Mr. Preece in support of his argument as to the working capacity of a duplex circuit.

To me, Sir, there is a savour of presumptuous audacity in dragging the name of that eminently-scientific gentleman into this paltry dispute; indeed, to my mind, it is simply a disparagement of his great ability for any one professing to have a knowledge of electrical matters to imply that, in making the remarks quoted by Mr. Dunn, any reference to single needle duplex was intended. It must have been to the "Morse" that Mr. Preece's remarks applied; and if Mr. Dunn did not know or consider this, he is to be pitied rather than blamed. Mr. Dunn concludes his long-drawn epistle by telling us in the same high-flown style that the chief point of novelty and interest lies in the conversion of an ordinary single needle instrument into a complete duplexed instrument by its being *cut in two*, and the single wound coil utilised in the manner previously described, adding that this is an entirely *new departure*, and one which he ventures to say will be largely taken advantage of by other telegraph superintendents, &c. Now, Sir, allow me to ask if anything more ludicrous ever got into print. Where, I ask, is the novelty? Where the point of interest, and where, whatever its meaning, the *new departure* to be largely taken advantage of by telegraph superintendents? I now leave Mr. Dunn, with no envious feelings, in full possession of his adopted "Bairn," the ancient system of single needle duplexing, and if, perchance, he or any other party should by perseverance and skill succeed in maturing this "Bairn" to a position of usefulness to the railway service, I shall be as ready to forgive the attempt of piracy as I am to expect that a "sorry mistake" has been committed.

Arthur E. Gilbert.

April 18*th*, 1887.

Sparking in Telegraph Relays.

I should have stated in my previous communication that the apparatus mentioned *is* automatic, transmitting 10,800 currents per minute, with a play of less than $\frac{1}{300}$th of an inch, and the volume of current flowing when the circuit is closed = 0·32 of an ampère.

Wm. Clark Fisher.

What is a Filament?

This question has been frequently asked, also discussed in the pages of the ELECTRICAL REVIEW and ably dealt with in your leading article some short time since, but no one yet appears to have given a solution of this query. On page 203 of your journal, one able correspondent, who signed himself under the *nom de plume* of "Filacer Filacium," gives a very interesting description of its meaning as published in the pages of an ancient dictionary, but this description only refers to it as from medical, botanical and physiological points of view. No one has, however, attempted to give a description of the various vegetable and metallic filaments in existence. I therefore venture to do this, as they are practically the only kind of materials which are suitable and that can be used as a carbon conductor for producing electric light by incandescence.

Under these circumstances perhaps you will permit me to record a few facts relative to the subject, as it may throw some additional light upon the question and tend to solve the above problem.

I will explain the meaning of the various vegetable filaments as described by several nations. Firstly, I find the ancient Greeks speak of filaments or fibrous grass, as used by them for making mats. The Turks speak of filaments of fibre used in carpet making. The Russians speak of filaments of flax for linen making. The Egyptians of filaments of siligineus for weaving purposes. The Italians of filaceous filmus, filaments of small threads. The Indians of filaments of cocoa fibre. The Chinese of filaments of silk. The Japanese of filumous floss silk (but these two latter materials are, however, of a different species and cannot be so successfully charred or carbonised as fibrous fibres). Then I find the Swiss speak of filaments of straw for plaiting purposes. The Norwegians speak of filanders of moss, and the Irish allude to filaments of flax and peat moss, which latter substance, when properly carbonised, makes a good and pure carbon of low conductivity, and is therefore well adapted as a light producing medium for incandescent lighting.

Next come the various metallic and mineral filaments, comprising asbestos, mocha stone, mica, gold, platina and iridium.

Now, Mr. Edison's description of a so-called filament is neither of the above substances, but in reality a carbonised carbonaceous substance or compound, consisting of lampblack, cotton, thread, wood splints, and shreds or peeling of bamboo cane, neither of which materials can be properly construed into a filament in its true scientific meaning. Neither do Mr. Edison's specifications clearly explain or state whether his selected materials are used in combination with each other or not.

It is, therefore, difficult to imagine any variety of carbon of a nature further removed from the filaments and fibrous carbon materials above referred to, than the mixtures which Mr. Edison rolled out and claimed as a filament, in the much-contested patent of November, 1879; and it is further well-known by practical lampmakers, that to make a carbon filament for producing the modern incandescent lamp, according to his patent, is a practical and scientific impossibility; and as Mr. Edison has no moral claim to be called the pioneer of the modern incandescent lamp, he is only entitled to that which his patent clearly describes, as there are other inventions since brought out which are in full force, and are consequently duly protected by Her Majesty's seal, for which the Government have received the fees, and have granted protective rights to the various owners thereof.

The question is what is the true definition of the now so-called carbon filament, which was previously described by Harrison, deceased, in an earlier patent, as being composed of carbonised silk, lampblack, &c., and used by him in combination with other materials as a medium for producing incandescent light.

This filament described by Harrison is, undoubtedly, far nearer the present modern incandescent lamp than that described by Mr. Edison in his patent, No. 4,576, 1879, and the recent incandescent lamp litigation is only a preliminary skirmish to the many battles which will have to be fought in the incandescent lamp war.

Arthur Shippey.

Secondary Batteries.

In your article, *re* the above, contained in this week's issue of the REVIEW, you refer to what may be termed a serious imperfection in the construction of secondary batteries, especially when intended for electric locomotion. But you do not mention another very important application of these batteries, viz., that of train lighting, and to which your remarks apply with equal force.

Manufacturers of secondary batteries or accumulators, cannot be too strongly impressed with the importance of *mechanical strength*, even at the expense of a little electrical efficiency, if need be, when train lighting is the object to be attained.

While on this subject, I may mention one or two other little points, which deserve some attention.

1st. The boxes should be so constructed as to prevent the possibility of the liquid splashing over.

2nd. They should be thoroughly insulated.

The former of these is of special importance, as the splashing over necessitates the addition of *acid* as well as water, occasionally, otherwise the liquids become too weak and an increase of resistance results, this in spite of the cells being kept fully charged.

F. W. Cooke, S.T.E.

April 19*th*, 1887.

Technical Training.

As you are inviting criticism upon the system of technical education pursued at the establishments of the City and Guilds of London Institute, may I be permitted to take the earliest opportunity of asking such of your correspondents as may respond to your enquiries to be explicit as to what part of the system they are criticising. In brief, I would ask them not to confuse together any of the following five things, each of which is distinct and independent.

1. The system of instruction at the Central Institution, Exhibition Road.
2. The system pursued in the day courses of the Finsbury Technical College.
3. The evening classes of the Finsbury Technical College.
4. The "special" lectures at the Finsbury Technical College.
5. The system of technological examinations conducted by the City and Guilds Institute, preparatory classes for which are held in many parts of the Metropolis and in many science schools throughout the United Kingdom.

Further, as I find the mistake is frequently made, I would beg that no confusion be made between the Finsbury Technical College and the City of London College in Moorfields, or between the Finsbury Technical College and the Cowper Street Middle Class Schools. Both these institutions, I believe and know, to be doing excellent work, but they are in no way connected with the work at Finsbury, saving in so far as students sometimes pass from one institution to the other.

Silvanus P. Thompson.

April 18*th*, 1887.

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